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Evaluation of the Standard Sampling Technique for Suspended Solids

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EVALUATION OF THE STANDARD SAMPLING TECHNIQUE FOR SUSPENDED SOLIDS

BY

U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION VII

SURVEILLANCE & ANALYSIS DIVISION

TECHNICAL SUPPORT BRANCH

FIELD INVESTIGATIONS SECTION

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U. S. Environmental Protection Agency, Region VII
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Field Investigations Section

Gregory D. Reed, Ph. D.

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Abstract

The inconsistency of non-filterable solids data resulting from automatic sampling equipment used by the Surveillance and Analysis Division, Region VII, United States Environmental Protection Agency, was evaluated from a field sampling technique viewpoint. Resins and other solids of varying specific gravity and particle size were tagged with a metal salt or fluorescent material and added to a waste stream as a synthetic suspended solid to determine the collection efficiency of the samplers. Recovery of the metal salt or fluorescence was used as the indicator of solids recovery. A 832,000 liters per day (220,000 gallon per day) raw domestic wastewater flow was used to conduct the test. Recovery of solids in the hydraulic jump below the Parshall flume, and at the 0.6 depth in the approach channel above the flume was 25 percent below the theoretical homogeneous concentration indicated by the resin feed rate. The results indicate the need for a method of evaluating the wastewater characteristics for proper sample intake tube placement.

I. INTRODUCTION

The increases in population and technology create a larger and larger demand upon our water resources. The use of these waters produces various wastewaters that are released back into the hydrologic cycle. In order to protect the quality of water resources for aquatic life and reuse by others, the wastewaters generated must be cleansed of harmful impurities prior to their discharge. One of the problems in monitoring these inputs and discharges of wastewater treatment systems is the accurate quantification of any given constituent in the liquid stream. A sample that is representative of the total flow, not only for that moment, but also for the longer period of time is essential for the determination of the suitability of a wastewater for release into a natural receiving water. Fluctuations in the chemical and physical constituent concentrations found in wastewaters have a dramatic impact on the acceptability of the quality of that wastewater.

Several interrelated parameters are normally selected to monitor the performance of wastewater treatment works. One of these is the non-filterable solids (suspended solids) content. The nonfilterable solids (NFS) parameter was selected for this test program because previous work (2) has shown it to be the most difficult constituent to collect for representative samples. Since no primary analytical standard currently exists for the NFS test (1), NFS data

are subject to view with a skeptical eye. However, secondary treatment is defined by NFS and is a prime regulatory parameter on discharge permits and in municipal pretreatment ordinances for industrial users of the sewer system. Therefore, it is important to evaluate the valididty of the NFS data prior to making a decision of acceptability of an influent waste, discharge, or treatment system. Historically, the inference has been that when a liquid sample is withdrawn, by any process, all of the constituents are present in the same concentrations as existed in the original flow stream. Harris and Keffer (2) have indicated that the resulting NFS data for a raw municipal wastewater stream monitored concurrently with more than one commercial automatic sampler can vary by as much as 300 percent, depending on the type of automatic sampler used.

Parameter variation of this magnitude demands development of a method for evaluating the solids sampling capability of the numerous automatic samplers available. This study was directed toward determining if the standard sampling procedures used by the Surveillance and Analysis Division would in fact provide a truly accurate sample of the wastewater under study.

II. REVIEW OF PREVIOUS WORK

As the need for monitoring wastewaters grew, automatic sample collection became an economically attractive alternative to traditional manual methods. Data resulting from these automatic samplers have become an important element of the environmental decision making process. The impact of these decisions clearly indicate the need for wastewater samples which are truly representative of the source.

The characteristics of most wastewaters are constantly changing because of cyclical and diurnal variation. Additionally, there are temporary surges of the constituent concentrations. Intermittant grab samples do not average out these variations; consequently composite samples are used to blend together the highs and lows to form a more representative sample. Compositing, which requires numerous samples over a long period of time (i.e., 24 hours), requires too much manpower to be economically accomplished manually. Automatic compositors have been introduced to release the operator requirement and to improve the accuracy of the collected samples. There are many different types and forms of automatic samplers on the market. Shelley and Kirkpatrick (3) and Harris and Keffer (2) have provided detailed assessments of the most common samplers in use by describing the good and bad features of each piece of equipment. The difficulty in obtaining representative and reliable suspended solids data from automatic samplers has been demonstrated

by Harris and Keffer (2). Shelly and Kirkpatrick (3) have attempted to outline the characteristics of common sampling equipment so that monitoring of a given wastewater can be achieved with the proper equipment. However, even this type of assessment has not solved the solids sampling problems. An appraisal of the individual wastewater solids characteristics as well as the automatic sampler characteristics may be required to effectively select the monitoring equipment. An understanding of the types and range of solids that potentially can be found in wastewater will provide a clearer insight of the magnitude and complexity of the solids monitoring problem.

A. Solids in Wastewater

Domestic and industrial wastewaters contain highly variable amounts of dissolved, colloidal, and suspended solids. Because of the large number of sources, wastewater solids are found in a variety of sizes and densities. Approximately 75 percent of municipal suspended solids are organic and approximately half of the organic solids are settleable (4,5). Non-filterable solids are generally considered to be anything larger than 0.45 micron with settleable solids assumed to be larger than 10 microns. The specific gravity of these solids ranges from less than unity for floatable solids to a maximum around 2.65 for grit and higher for certain industrial wastes. Approximately 30 to 40 percent of the organic content of raw municipal wastewater

is contained in solids that will tend to settle when put in a quiescent condition. These solids may become part of the bed-load in a wastewater pipe or channel.

The separation and distribution of solids that occurs in gravity flow systems is controlled mainly by the settling velocity of each particle. The settling velocity is, in turn, a function of the particle size, shape, density or specific gravity, and drag coefficient with a possible settling enhancement from natural flocculation (6). Because of the large variation of particle characteristics found in domestic wastewaters, the separation and distribution cannot necessarily be predicted for any one parameter. A large organic particle with a specific gravity just slightly greater than one could have the same settling velocity as a small sand particle with a specific gravity of 2.65. If the settling effects of a particle were the only controlling parameters, all of the suspended solid particles in a wastewater would settle out of the main flow stream given a long enough channel. However, there is a flow velocity that, when exceeded, will entrain or scour the settling material (7,8). For a given flow situation, some of the suspended solids will remain in suspension and another portion will eventually settle to the bottom. Therefore, the most representative sample location will be at a different position for different wastewaters.

Position of the sample intake tube becomes just as important as intake configuration and sample transport mechanism. In most wastewaters, there is a nonuniform distribution of solids from the top to the bottom of the channel.

B. Settling Characteristics

Suspended solids in a stream flowing under perfectly laminar conditions would be expected to settle to the bottom of the channel at a rate determined by their settling velocity. Eventually all of the suspended solids would drop to the bottom. This principle is used in settling systems, such as water and wastewater sedimentation tanks, to provide for solids removal. However the conditions involved in the transport of wastewater from one place to another are very seldom laminar in nature.

Turbulent flow presents a different condition in terms of the solids distribution. Intuitively, we would expect the lighter, smaller solids to be more uniformly mixed than the heavier, larger solids. In general, the solids that have settling velocities, in the Stoke's law range (N_{Re}<.1) would be distributed more or less uniformly. An inspection of the settling velocity relationship for the Stoke's law region (N_{Re}<.1)

$$V_s = \frac{g}{18} \frac{d}{v} (s.g. - 1)$$

where: V_s = settling velocity of the particle, L/t

g = acceleration of gravity, L/t^2

d = particle diameter, L

v = kinematic viscosity, L^2/t

s.g. = specific gravity of the particle

and the Reynold's number equation; $N_{Re} = \frac{Vd}{v} = \frac{g}{18} \frac{d^3}{v} (s.g. - 1)$ reveals that at constant temperature, many combinations of particle size and specific gravity will produce a condition that would result in a uniform distribution of solids. Therefore, uniform distribution is not necessarily restricted to low specific gravity materials.

The conditions of the transition zone ($0.1 < N_{Re} < 1$) produce progressively more pronounced variations in the distribution of solids from the top to the bottom of the channel. These conditions create the problem of sampler intake subsystem placement in order to achieve a representative sample. Since there are a large variety of particle sizes and specific gravities found in most wastewaters, there is no single particle settling condition that can be used to predict the position of the concentration that is representative of the flow as it would have been under homogeneous conditions.

C. Sampler Evaluation

Automatic wastewater samplers are available commercially that employ several different mechanisms and features for the transferral of

the wastewater from the flow stream to a sample container. The characteristics of these mechanisms that affect the solids sampling capability are of the most importance for this study. Most of the samplers use a pump, either peristaltic (the most popular), piston, impeller, or vacuum. Some use a direct withdrawal into a container under a vacuum. Whichever method is used, the velocity in the intake tube should be controllable and the mechanism should be able to pass the solids that are picked up in the intake tube.

The intake velocity is an important parameter that must be controlled. Studies (3) have indicated that the velocity should be equal to the free stream velocity with a minimum criteria of 0.79 to 1.18 meters per second (m/sec) [2 to 3 feet per second (fps)]. The minimum velocity provides for protection against settling of particulates in the intake tube during collection. Discussions by Shelley and Kirkpatrick (3) have emphasized the importance of isokinectic conditions for particulate sampling.

A major problem in wastewater sampling is blockage of the intake tube by solids in the wastewater. Small diameter tubes aggravate this problem, so tubes with inside diameters of at least 1 centimeter (cm) [0.38 inch (in.)] are recommended. The larger sizes reduce plugging but do not entirely eliminate the problem; consequently, automatic purging of the intake lines at regular intervals in the sampling cycle is very important to continual operation.

The primary question pertaining to sampling methodology that has not been answered is where to place the intakes to obtain a sample that is representative of the total flow stream. This study was concerned primarily with the recovery of solids with a specific gravity greater than one and does not address the problem of floating solids.

D. Standard Sampling Procedure

The standard sampling procedure used by the Surveillance and Analysis Division of Region VII on raw wastewater is as follows. A plastic or aluminum intake tube is positioned in the wastewater flow such that it is opening directly into the flow. The location of first choice is the mid-depth of a hydraulic jump. In the absence of a jump, the tube is placed in the throat of a Parshall flume or at mid-depth in the approach channel. The tube is connected to an automatic sampler equipped with a suction device capable of withdrawing the sample at a transport velocity equal to or greater than the stream flow velocity but always greater than 1 fps (0.3 mps). For most of the better currently available commercial wastewater sampling equipment, the intake line is purged with air prior to the withdrawal of each sample. The samples are withdrawn at specified time intervals into individual containers.

It is the validity of the NFS samples collected by this method that is being investigated in this study.

III. Procedure

The purpose of this study was to determine if the standard sampling procedures would, in fact, accurately recover an artificial wastewater solid that was present in a wastewater flow at a known concentration. The investigative site was a small, package, activated sludge treatment plant, located on the south side of Kansas City. A sketch of the test facility is shown in Figure 1. The plant was equipped with a 7.6 cm (3.0 in.) Parshall flume with 2 meters (m) [5 feet (ft)] of rectangular approach channel. The normal flow rate of wastewater was approximately 831,600 liters per day (l/day) [220,000 gallons per day (gpd)] and provided 15.2 cm (6 in.) of depth in the approach channel. The facility received domestic waste only and was located within 1.6 kilometers (km) [1.0 mile] of the residential area that it served. According to past records, the NFS varied from 96 to 190 mg/l and the flow has reached as high as 1.55×10^6 l/day (410,000 gpd) after a rain.

A sewer line junction box was located 20 m (50 ft) upstream from the flume. The box was 2.4 m (6.0 ft) by 2.4 m (6.0 ft) by 1.6 m (4.0 ft) deep and provided a convenient location to add the synthetic solid. The synthetic wastewater suspended solid was applied at a known rate with a BIF Omega Model 22-01 low rate feeder* which was positioned to deposit the solid directly into the wastewater flow as shown in Figure 1. The channel changed direction in both

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* BIF, 345 Harris Avenue, Providence, Rhode Island 02901

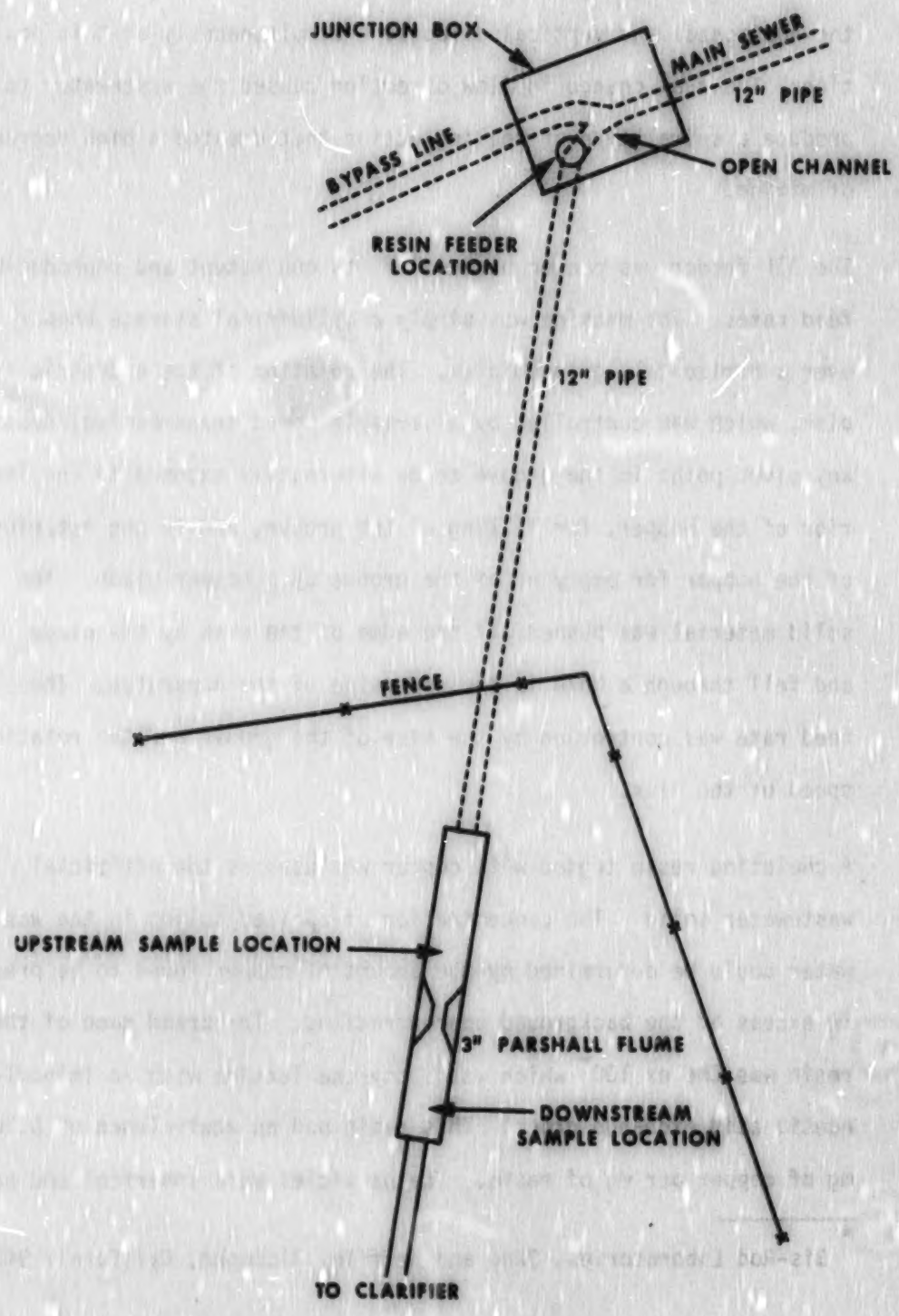

Figure 1: Sketch of the sampling test facility

the horizontal and vertical directions simultaneously at this position. The dual change in flow direction caused the wastewater to produce a spiral type of rolling action that created a high degree of mixing.

The BIF feeder was chosen because of its consistent and reproducible feed rates. The machine was simply a cylindrical storage hopper over a horizontal, grooved disk. The rotation of the eccentric disk, which was controlled by a variable speed transmission, caused any given point in the groove to be alternately exposed to the interior of the hopper, for filling of the groove, and to the exterior of the hopper for emptying of the groove by a scaper blade. The solid material was pushed off the edge of the disk by the blade and fell through a hole in the underside of the apparatus. The feed rate was controlled by the size of the groove and the rotational speed of the disk.

A chelating resin tagged with copper was used as the artificial wastewater solid. The concentration of applied solids in the wastewater could be determined by the amount of copper found to be present in excess of the background concentrations. The brand name of the resin was Chelex 100* which was a styrene lattice with an iminodiacetic acid exchange group. This resin had an equivalence of 0.104 mg of copper per mg of resin. The particles were spherical and had

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* Bis-Rod Laboratories, 32nd and Griffin, Richmond, California 94804

a specific wetted gravity of 1.15. Several different size particles were used to provide different suspension and settling characteristics.

In addition to the resin, a number 17 silica grade of Ottawa quartz sand* (specific gravity of 2.65) coated with an arc yellow Day-Glo** fluorescent dye and sealed with plastic was fed to obtain bed load recovery data. The intent was to use the readings from a fluorometer as the indicator of the concentration of solids recovered during the sampling process. This attempt was not successful because of apparent interferences in the wastewater system or in the measurement technique. The data reported is from the resin applications only.

Four sampling points were examined, three one-foot upstream from the flume in the center of the approach channel at the 0.2 and 0.6 depth, on the bottom of the channel, and one downstream in the center of the existing hydraulic jump. The tube opening in the jump was located 15 to 30 cm (6 to 12 in.) downstream from the leading edge of the stationary wave. In addition, background copper samples were collected in the sewer upstream from the resin feeder by an automatic sampler. All of the intake tubes were 1.0 cm (0.38 in.) inside diameter (ID) Tygon tubing positioned to open directly into the flow stream (similar to a pitot tube arrangement).

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* Ottawa Silica Company, Ottawa, Illinois

** Switzer Brothers, Inc., Cleveland, Ohio

The samples were withdrawn directly from the channel into one-liter cubitainers by a variable speed sampler built in the Region VII laboratory. (See Attachment #1). The individual depth samples were not taken simultaneously. The samples were collected one at a time in the order given above with approximately 15 seconds required for each sample. The sampler utilized a variable speed peristalic pump controlled by purge and sample timers that could be adjusted to various cycles. The sampler was set so that the intake tube was completely purged with air prior to the collection of a sample. The sampler was located less than 0.5 m (18 in.) directly above the wastewater surface during sampling. The samples were mechanically collected in the same manner as they would be by an automatic sampler; namely, a purge of the line and on immediate collection of approximately 800 ml of the wastewater. The flow rate was measured by positioning a Sigmamotor Bubbler depth sensor in the channel and using the Parshall flume dependency on depth as the indicater of flow. The bulk velocity in the channel was measured by positioning an Ott meter* at approximately mid-depth.

A. Selection of the Resin

A weak acid cation exchange resin, Chelex 100 (a styrene divinylbenzene copolymer containing iminodiacetate functional groups), was chosen as the synthetic suspended solid because of its high affinity for copper, an element easily measured at small concentra-

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* Weathermeasure Corp., 3213 Orange Grove Ave., North Highlands, California 95660
Model F581 Water Current Meter

tions. This resin was used to take advantage of controllability of size, shape, and density. An additional advantage was the resistance of this material to elution of copper while suspended in raw domestic wastewater. Therefore the amount of copper found during analysis is a known function of the solids added based on the equivalence of the resin.

The equivalency of copper on the resin (mg of copper per mg of resin) is needed to convert the copper concentration in mg/l to solids concentration in mg/l. Since copper can be readily measured at concentrations below one mg/l, the amount of resin added to the wastewater could be kept relatively small while still obtaining reliable results. The volume of material required would prohibit a direct solids addition. Restrictions imposed by the feeding apparatus required the resin to be dry. Drying the resin interfered with mixing because of water surface tension. This problem was solved by applying a liquid detergent onto the resin before drying. This detergent effectively broke the surface tension and permitted complete suspension of the resin. The equivalency of the resin was determined after the drying had been performed by stripping the copper with nitric acid. The equivalency of the resins used varied from 0.102 to 0.108.

Both the copper and NFS tests were run on the samples. The samples were delivered unpreserved to the EPA Region VII lab* to prevent

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* 25 Funston Road, Kansas City, Kansas 66115

loss of suspended solids. In order to improve precision in the copper analysis, the entire sample was acidified after the NFS test.

B. Tagging The Resin

Approximately 225 grams (g) [0.5 lb.] of wet resin (around 75 percent moisture) was placed in a large ion exchange column. The column and resin was rinsed with deionized water. A four-fold excess of copper (16 percent copper sulfate solution) was eluted through the column. The excess copper was rinsed from the column with deionized water until no copper was detectable in the elutant.

The resin was then transferred to a Buchner funnel and the excess water removed by vacuum. The funnel was then filled with 7X brand laboratory detergent,* allowed to soak for a few minutes, and the excess was removed by vacuum. The resin was then dried at 50° C in a vacuum oven.

C. Copper Analysis

A 100 ml portion of the acidified, well mixed sample was added to a 250 ml Erlenmeyer flask. Five ml of concentrated nitric acid was added and the sample boiled down to about 50 ml. The sample was cooled and filtered through a Whatman number one paper filter to remove any solids. The filtrate was brought back to the original volume with deionized water. The copper measurement was performed

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* Linfro Scientific, Inc., Division of Flow Laboratories, Hamden, Connecticut 06514

on an Instrumentation Laboratories Model 453 atomic absorption spectrophotometer.*

D. Equivalency Determination

A 50-mg portion of the copper tagged resin was placed in a one-liter volumetric flask with a small amount of deionized water. The copper was dissolved from the resin with 10 ml of concentrated nitric acid. The resulting solution was diluted to one liter. The final solution was then analyzed for copper on the atomic absorption spectrophotometer.

E. Non-filterable Solids Analysis

A 25-ml portion (measured with a large tip pipette) of the blended, well mixed sample was filtered through a previously tared small Gooch crucible containing a glass fiber filter. The Gooch was dried at 105° C overnight. The crucibles were then cooled and reweighed.

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* Jonspin Road, Wilmington, Massachusetts 01887

IV. Results

A field sampling program was performed to measure the solids collection effectiveness of the most common automatic sampler mechanism utilized by the EPA Region VII Surveillance and Analysis Division; namely a peristaltic pump with 0.95 cm (0.38 in.) tubing positioned to open directly into the wastewater flow. Three different sized resins of the same wetted specific gravity (1.15) were fed into the wastewater flow to serve as the indicator of the effectiveness of solids collection in normal sampling procedures. The different settling characteristics of these resins was based on particle size; (1) 200 to 325 mesh [0.074 to 0.044 mm (0.0029 to 0.0017 in.)] in Stoke's law valid zone, (2) 50 to 100 mesh [0.297 to 0.149 mm (0.0117 to 0.00587 in.)] in the transition zone, and (3) 20 to 50 mesh [0.840 to 0.297 mm (0.0331 to 0.0117 in.)] in the Stoke's law invalid zone.

Resin number 2 was sampled under two intake conditions; (1) isokinetic'ly, at a free stream velocity of 0.27 m/sec (0.9 fps), and (2) at the recommended minimum of 0.76 m/sec (2.5 fps). The first condition is shown in Figure 2. The line connects the mean values at each depth sampled. The jump values (taken at mid-depth in the hydraulic jump downstream from the Parshall flume) are shown on the left as a reference of the relationship between that sampling position and the others. A homogeneous distribution would result in a resin ratio for all three depths of 1.0. The second condition is shown in Figure 3. There was no appreciable difference between

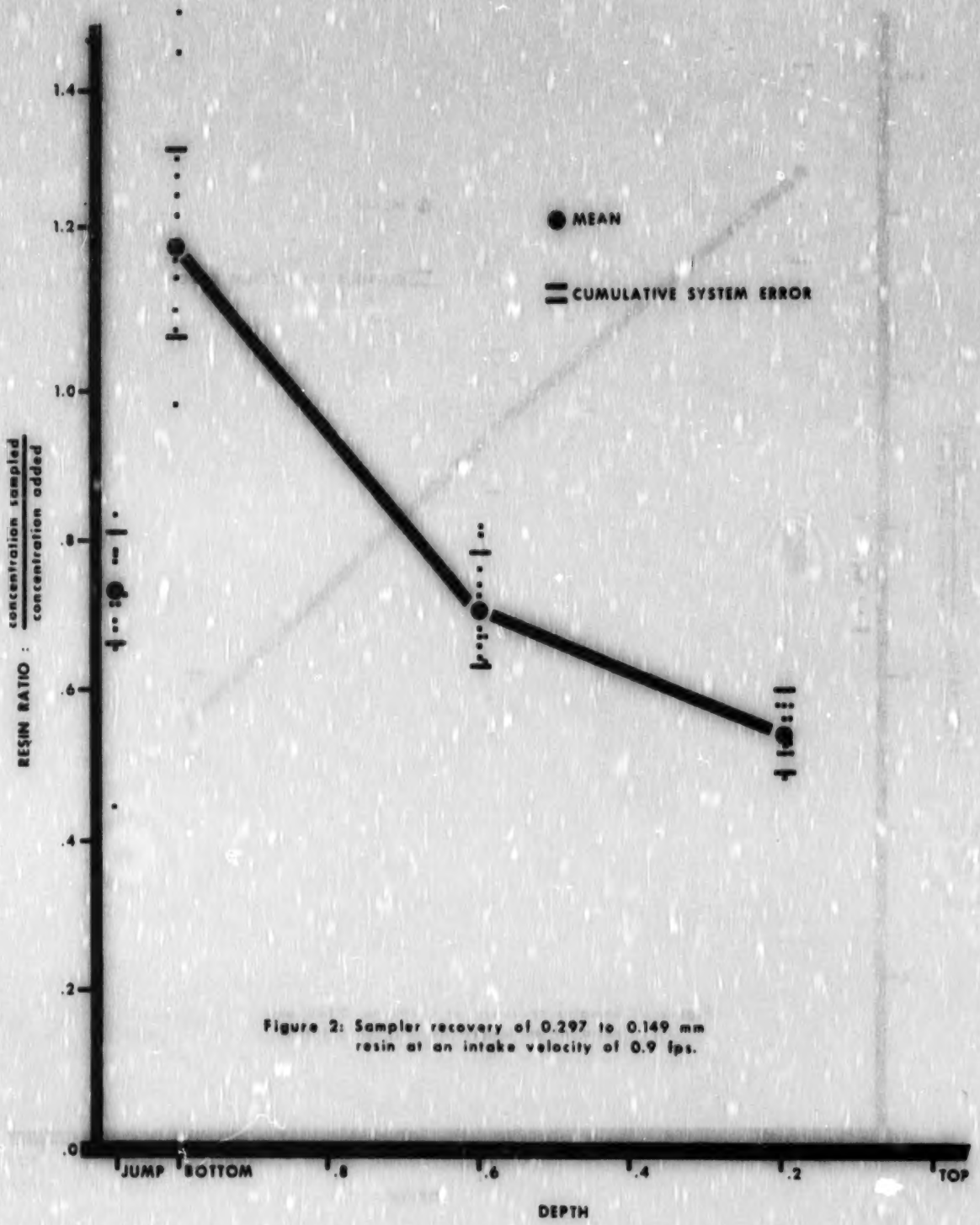

Figure 2: Sampler recovery of 0.297 to 0.149 mm resin at an intake velocity of 0.9 fps.

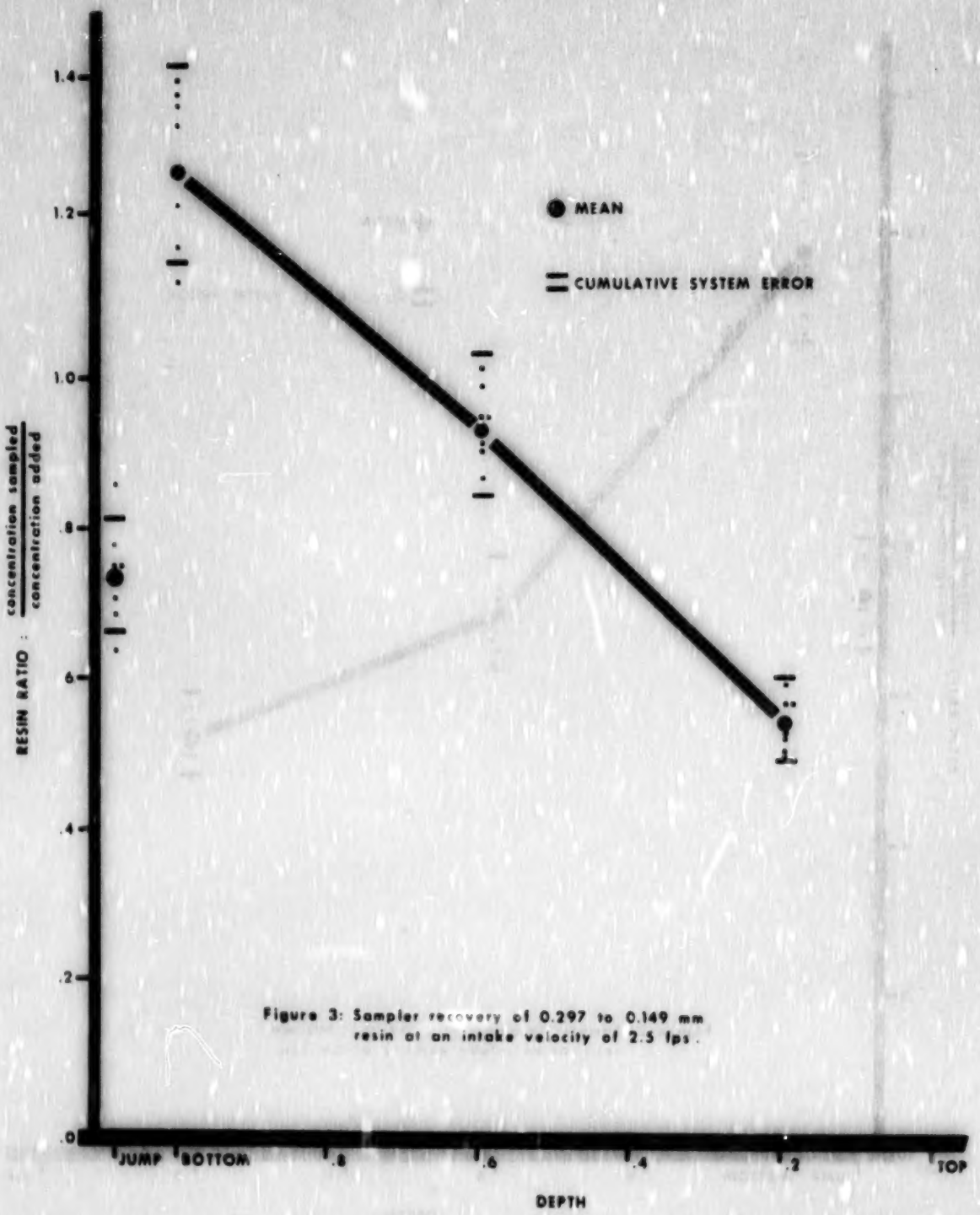

Figure 3: Sampler recovery of 0.297 to 0.149 mm resin at an intake velocity of 2.5 fps.

these two results except at the 0.6 depth, which may have been due to tube placement. Since there was no difference, and to help insure that all the solids were transported properly, all of the remaining samples were collected at an intake velocity of 0.76 m/sec (2.5 fps). Notice that the sample collected in the jump did not achieve full recovery of the resin, as is sometimes assumed.

The first condition was repeated on a different sampling day and the results are shown in Figure 4. The results were the same as the previous samples which were under different flow and solids conditions (it had rained two days prior to the first set of data).

The variation in the resin data was larger than expected but generally within the cumulative error of the equipment used to obtain the number (i.e., resin feeder ±2 percent, flow chart recorder ±2 flume ±4 percent, and copper analysis ±2 percent). The relative changes in recovery at each sample position with progressing sample collections are shown in Figures 5, 6, and 7 for the same conditions shown in Figures 2, 3, and 4, respectively. Although it is not shown as strongly in Figures 5 and 6, the curves in Figure 7 seem to indicate the recovery of resin was directly influenced by the flow rate. This possibility will be examined further for its implications on the results later.

The NFS was also measured for each condition and are shown in Figures 8, 9, and 10. The mean values are shown for comparison of the NFS

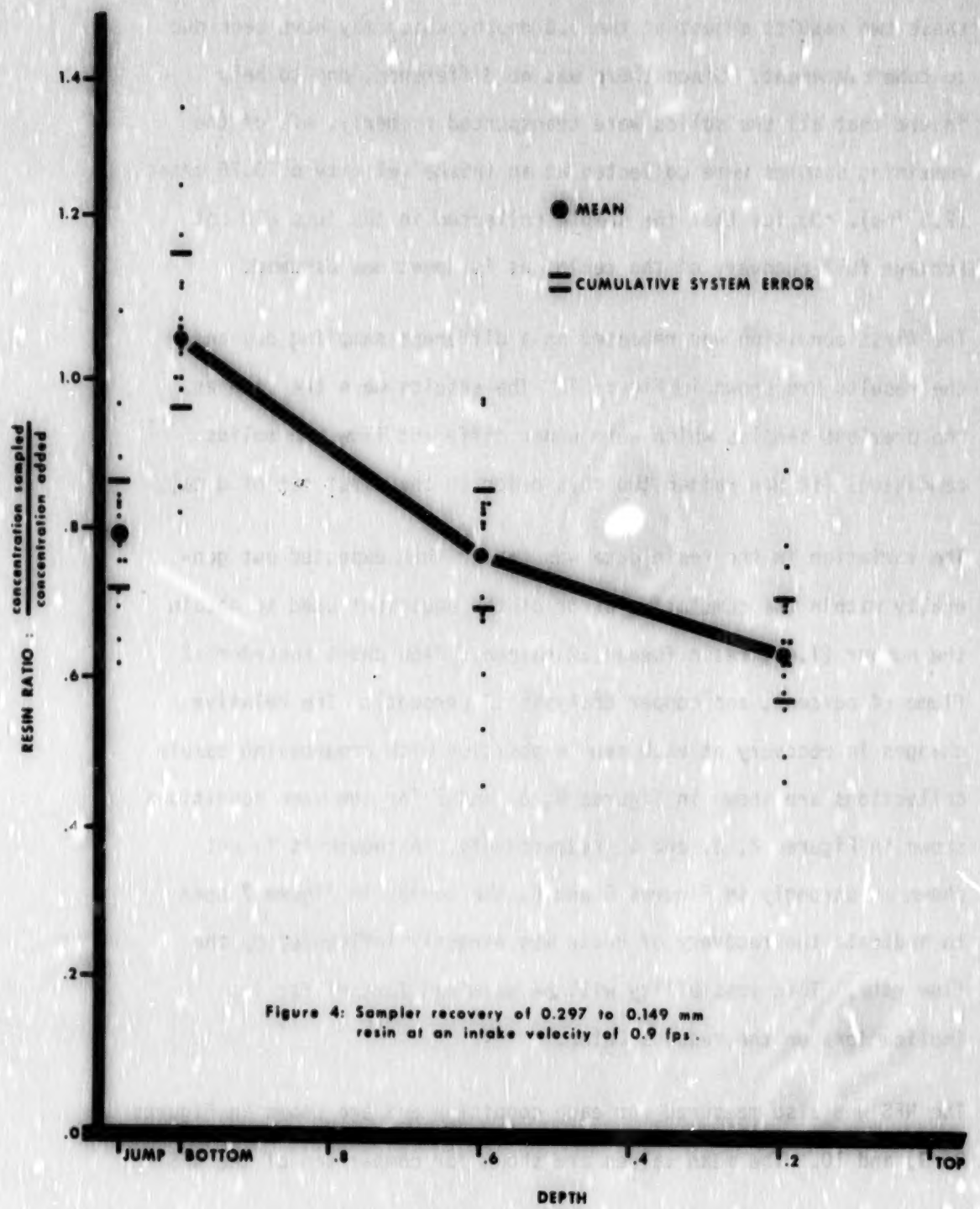

Figure 4: Sampler recovery of 0.297 to 0.149 mm resin at an intake velocity of 0.9 fps.

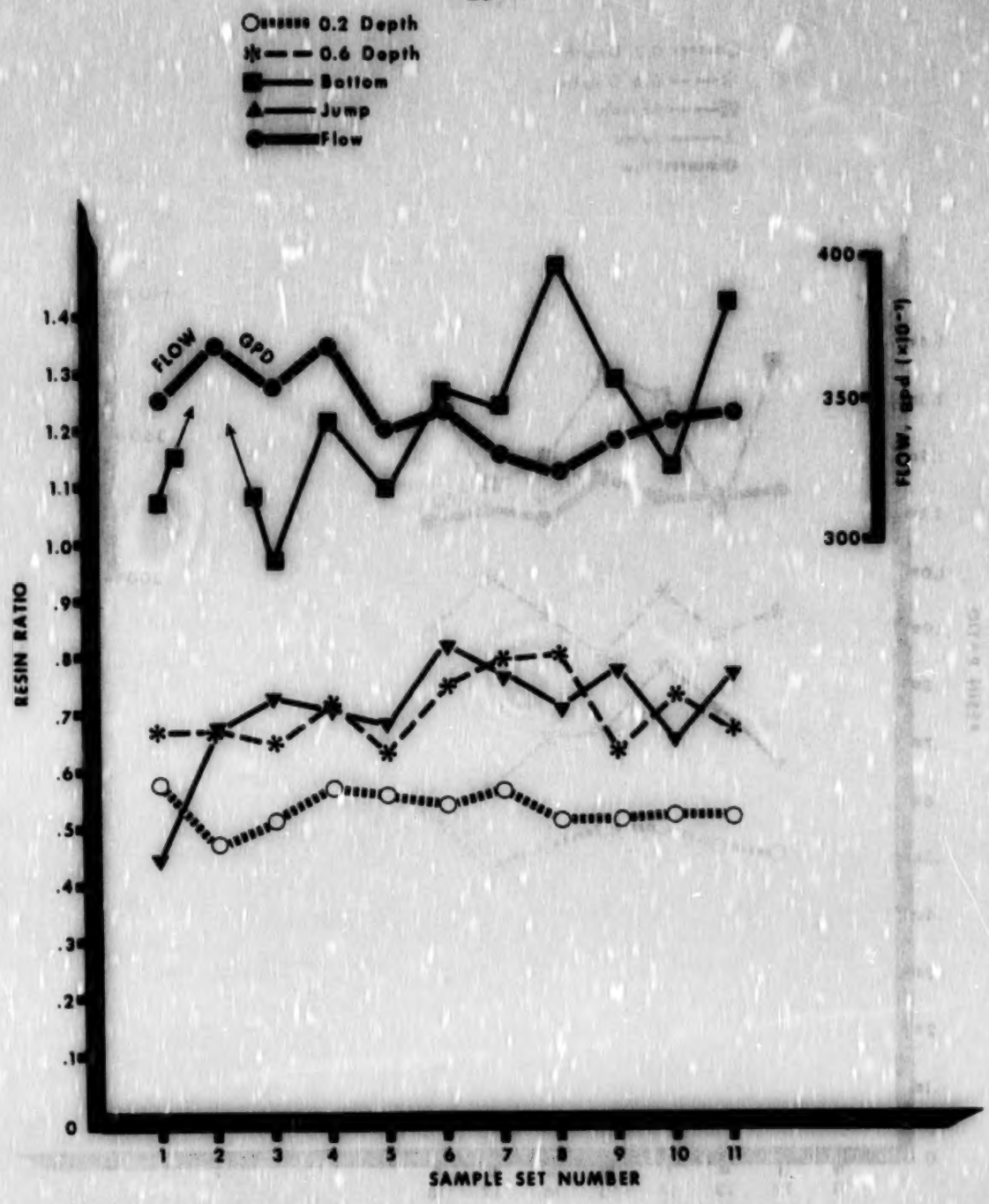

Figure 5: Relative recovery of resin #2 at an intake velocity of 0.9 fps.

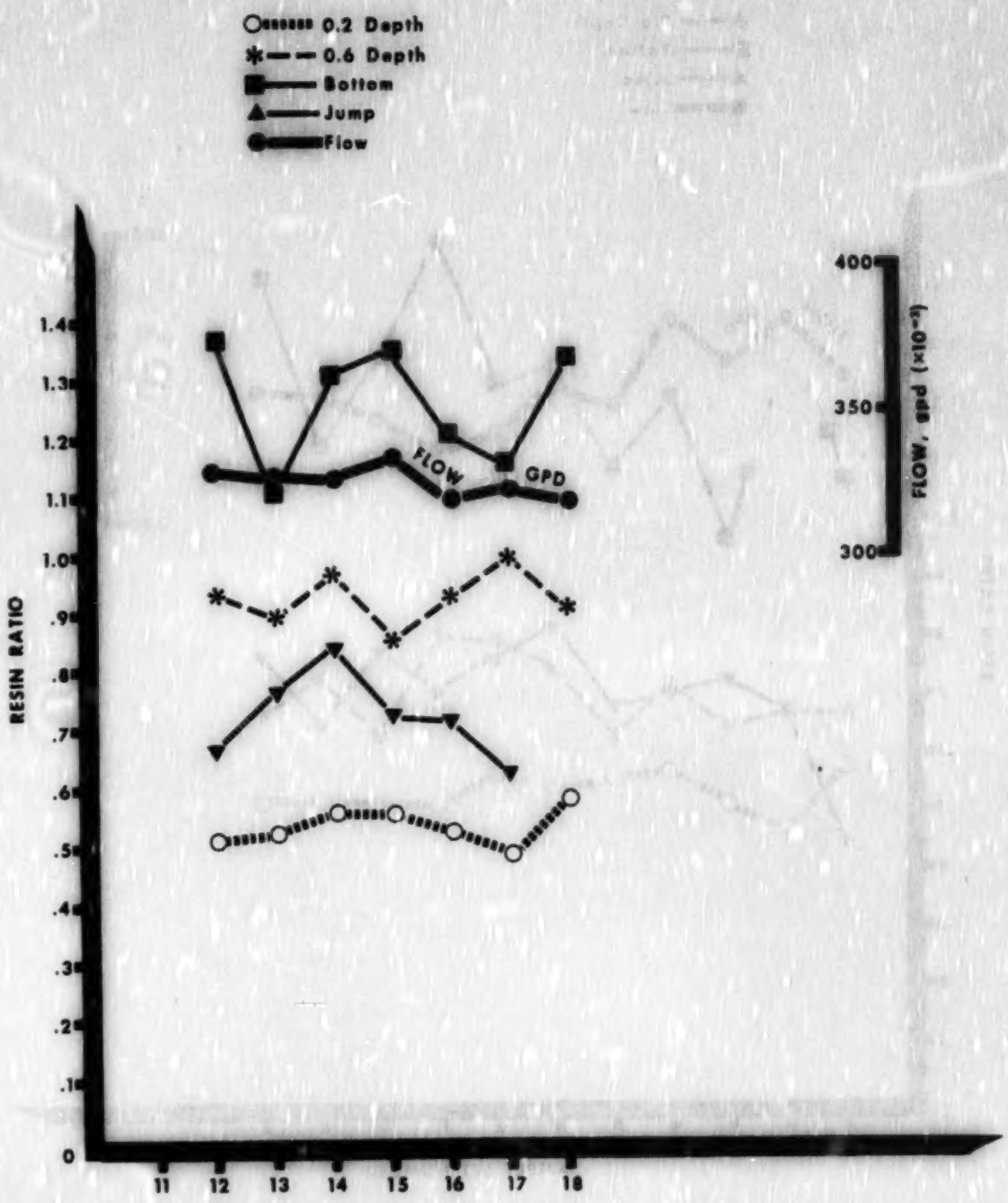

Figure 6: Relative recovery of resin #2 at an intake velocity of 2.5 fps.

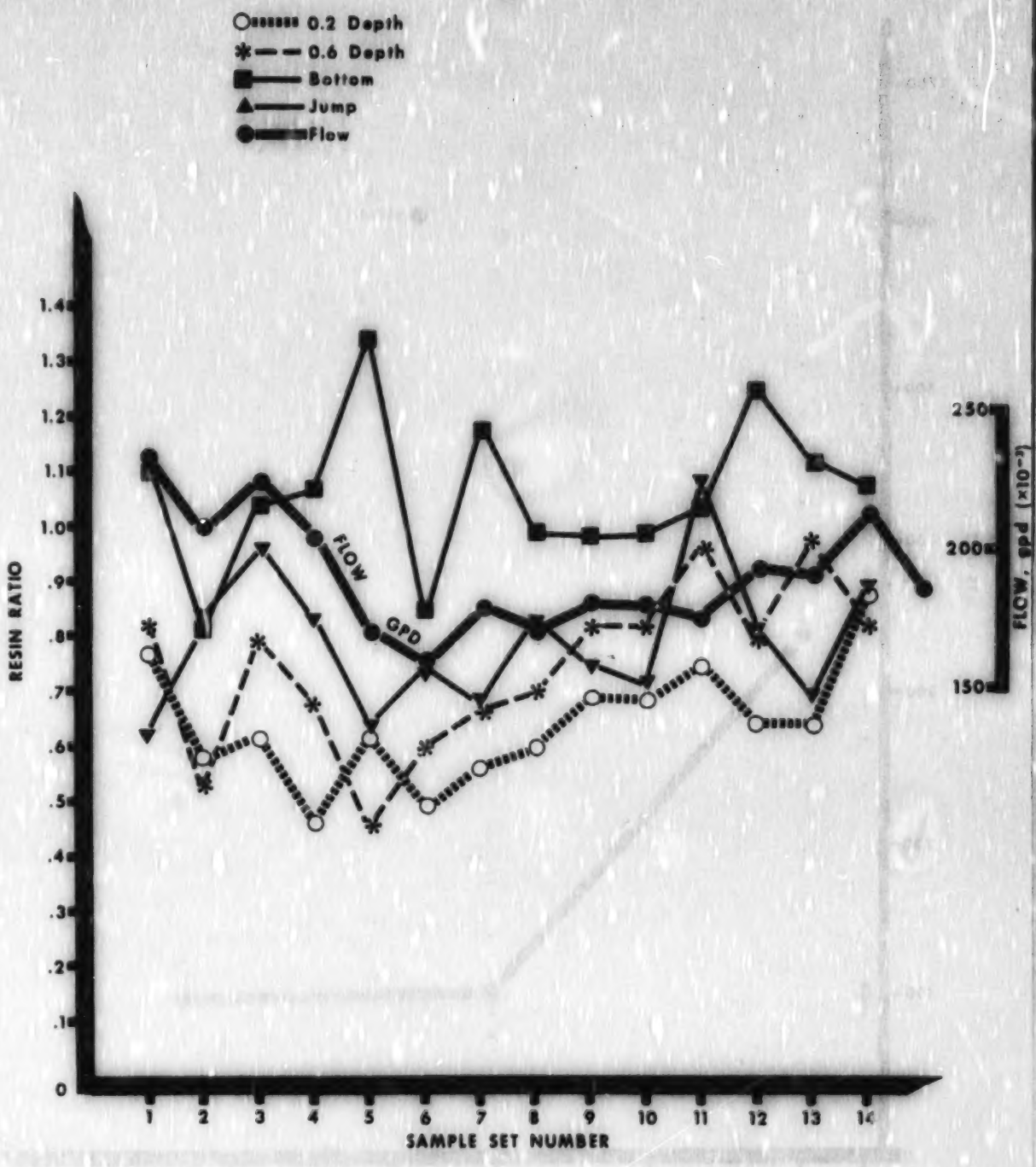

Figure 7: Relative recovery of resin #2 at an intake velocity of 0.9 fps.

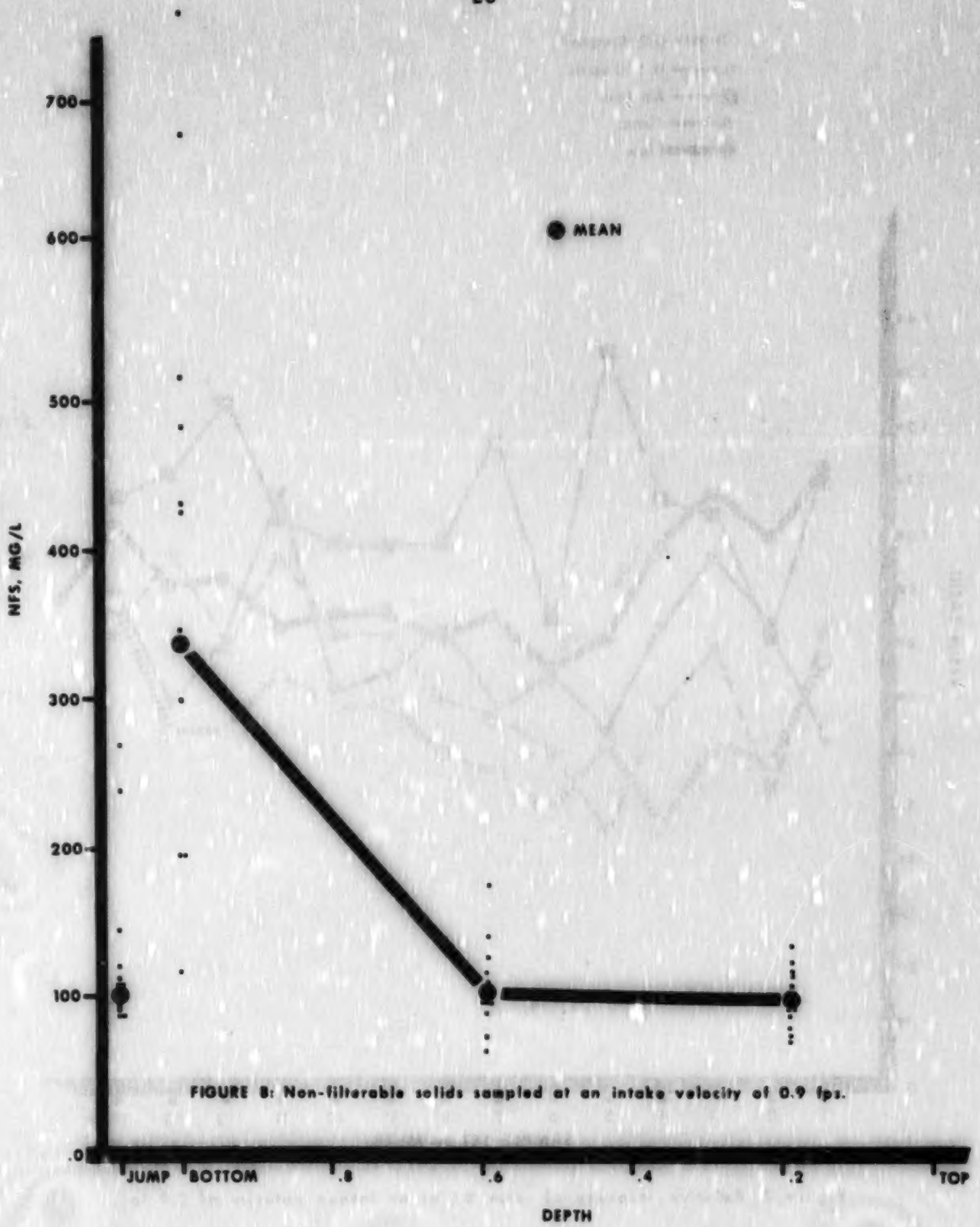

FIGURE 8: Non-filterable solids sampled at an intake velocity of 0.9 fps.

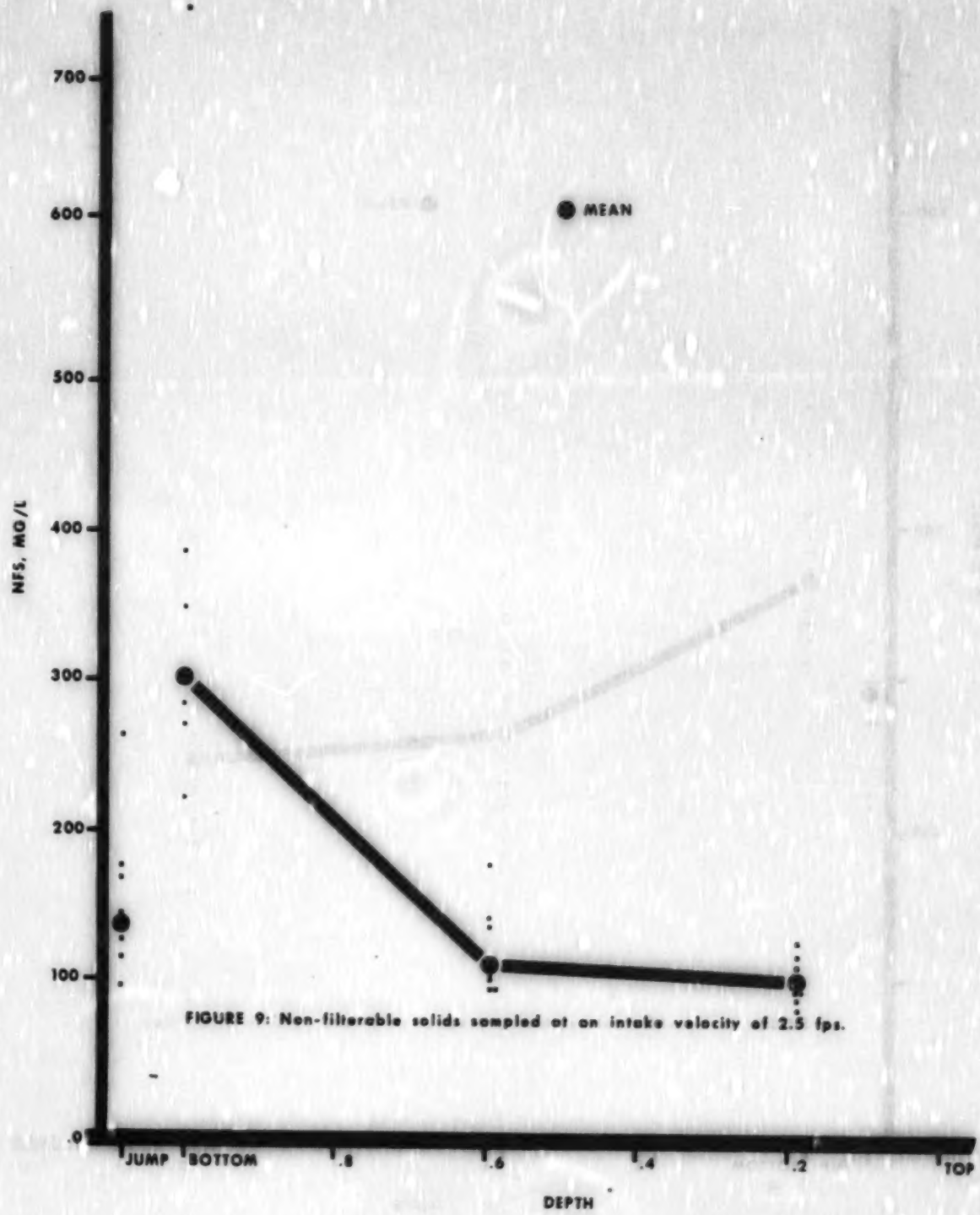

FIGURE 9: Non-filterable solids sampled at an intake velocity of 2.5 fps.

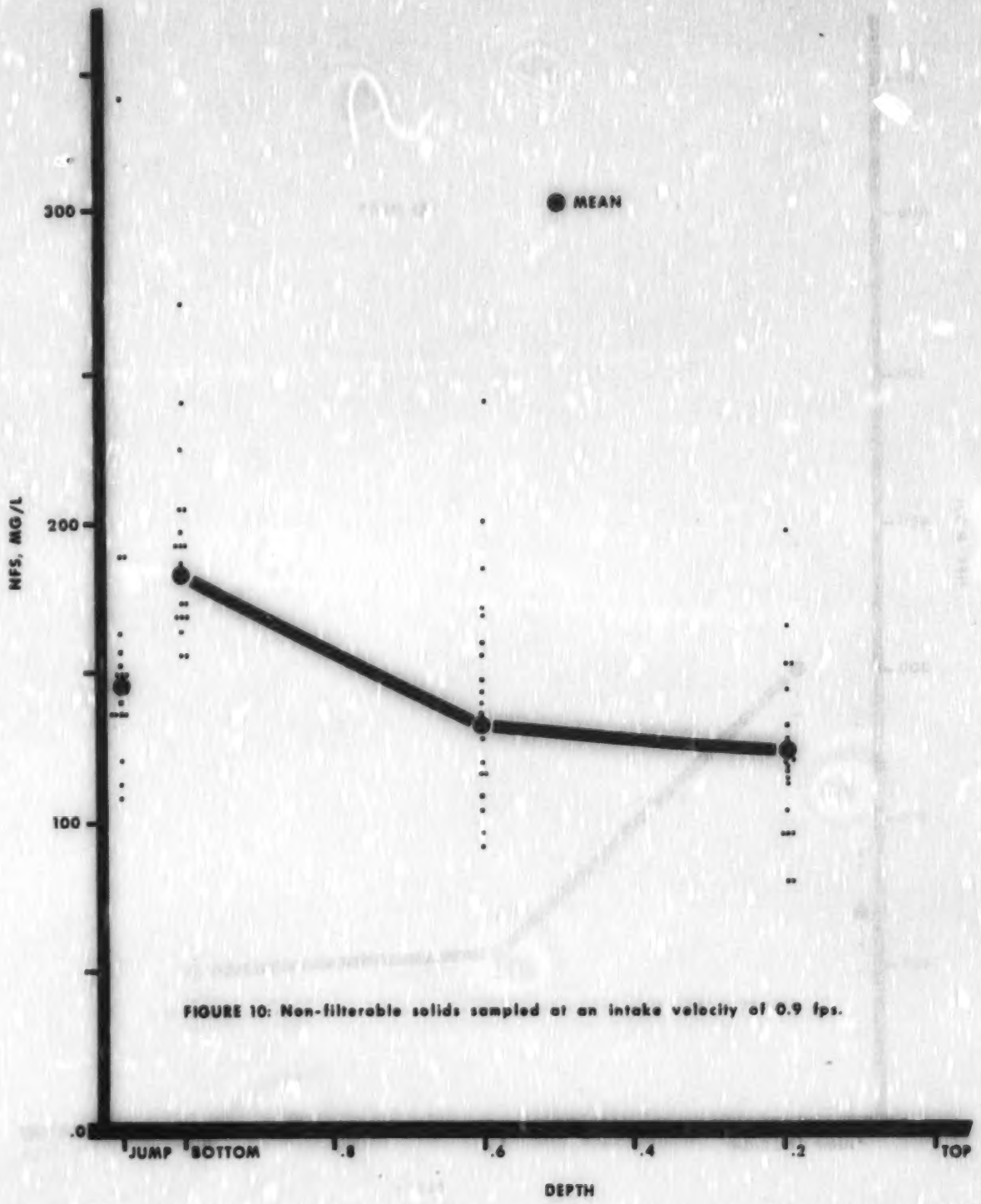

FIGURE 10: Non-filterable solids sampled at an intake velocity of 0.9 fps.

distribution to the resin distribution. The variation in the NFS data is primarily due to the change in wastewater characteristics with time of the day as is illustrated by Figure 11. The wide variation in the bottom sample results illustrates the difficulty in obtaining a representative sample. The distribution of NFS followed approximately the same pattern as resin number 2.

Resin number 1 was small enough to be governed by the conditions under Stoke's law. Therefore, a nearly uniform distribution of resin was anticipated. The results of the sampling test are shown in Figure 12. The variation of this data was the most severe of any of the sampling test. It was observed during sampling that this resin was not entirely distributed as discrete particles. The particles had a tendency to coalesce, possibly from influences of surface charges induced in the tagging and drying procedure or a reocurrence of a hindrance to dispersion by surface tension forces or a surface wetting problem.

An examination of the variations in concentration with each progressive sample shown in Figure 13 reveals that the unusually high or low values were accompanied by off-setting values at another sample position. The resin was totally recovered when looking at all three depth measurements together, even though an individual value may have been high or low.

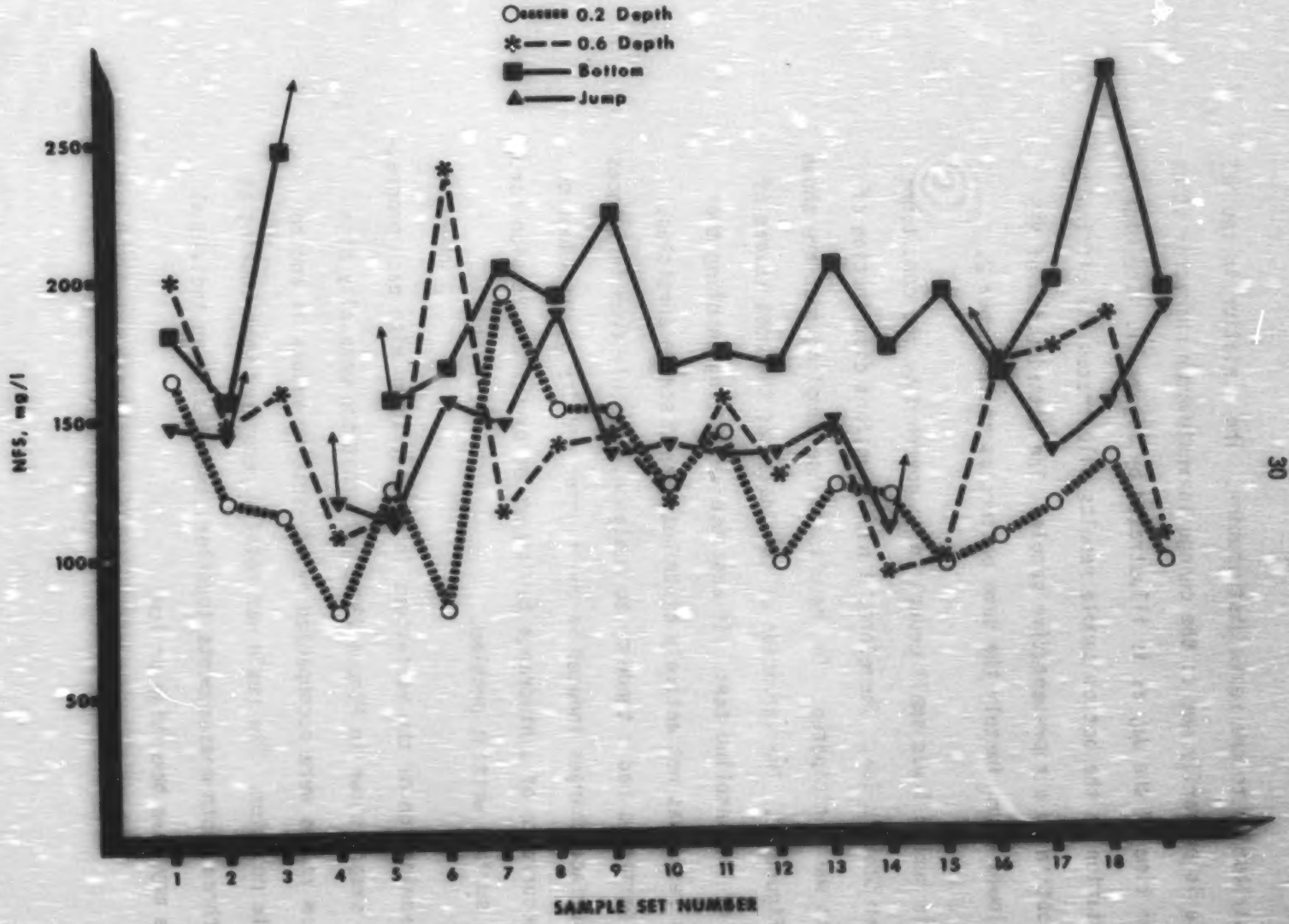

FIGURE 11: Relative variation of the non-filterable solids as a function of sample time.

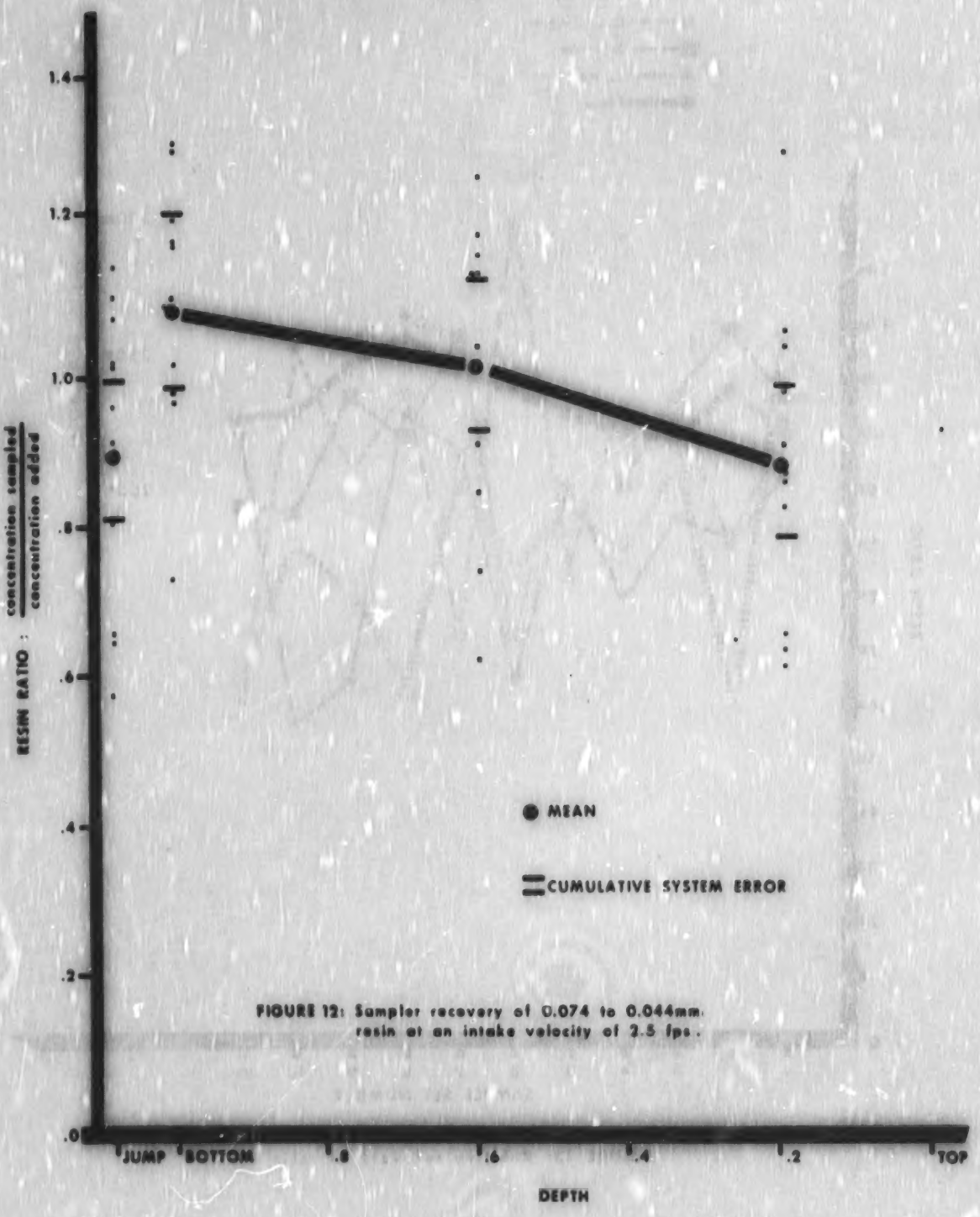

FIGURE 12: Sampler recovery of 0.074 to 0.044mm. resin at an intake velocity of 2.5 fps.

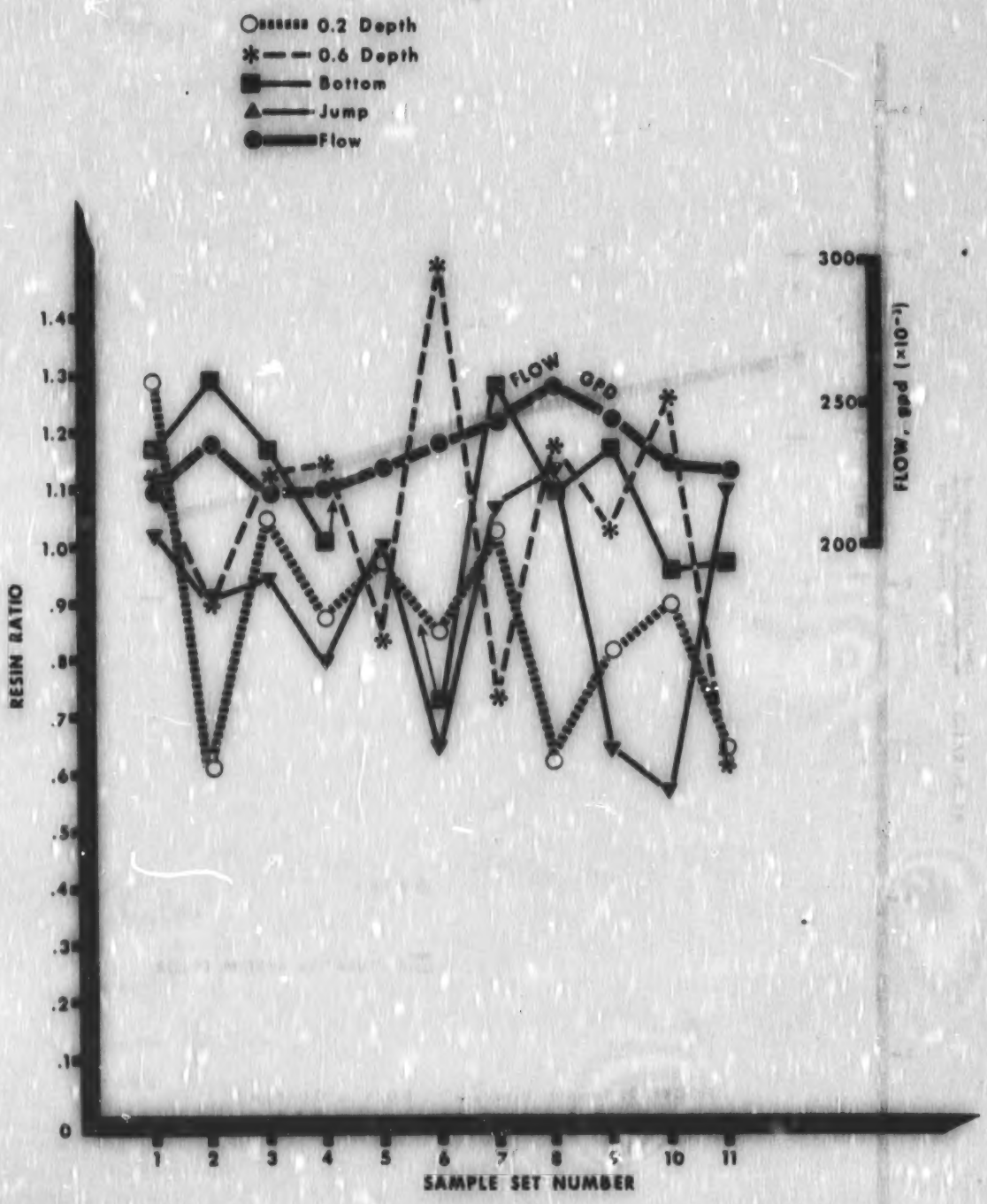

FIGURE 13: Relative recovery of resin #1

Resin number 3 was the largest tested and had characteristics that put it in the category where Stoke's law was invalid. This resin was expected to exhibit a very marked difference in concentration from top to bottom. The resin recovery is shown in Figure 14. The resin concentrations for the bottom samples were much lower than had been expected. The other values were generally in the range anticipated. The recovery as a function of sample time shown in Figure 15 illustrates the apparent sampling problem for the bottom sample position and the consistency of the other positions.

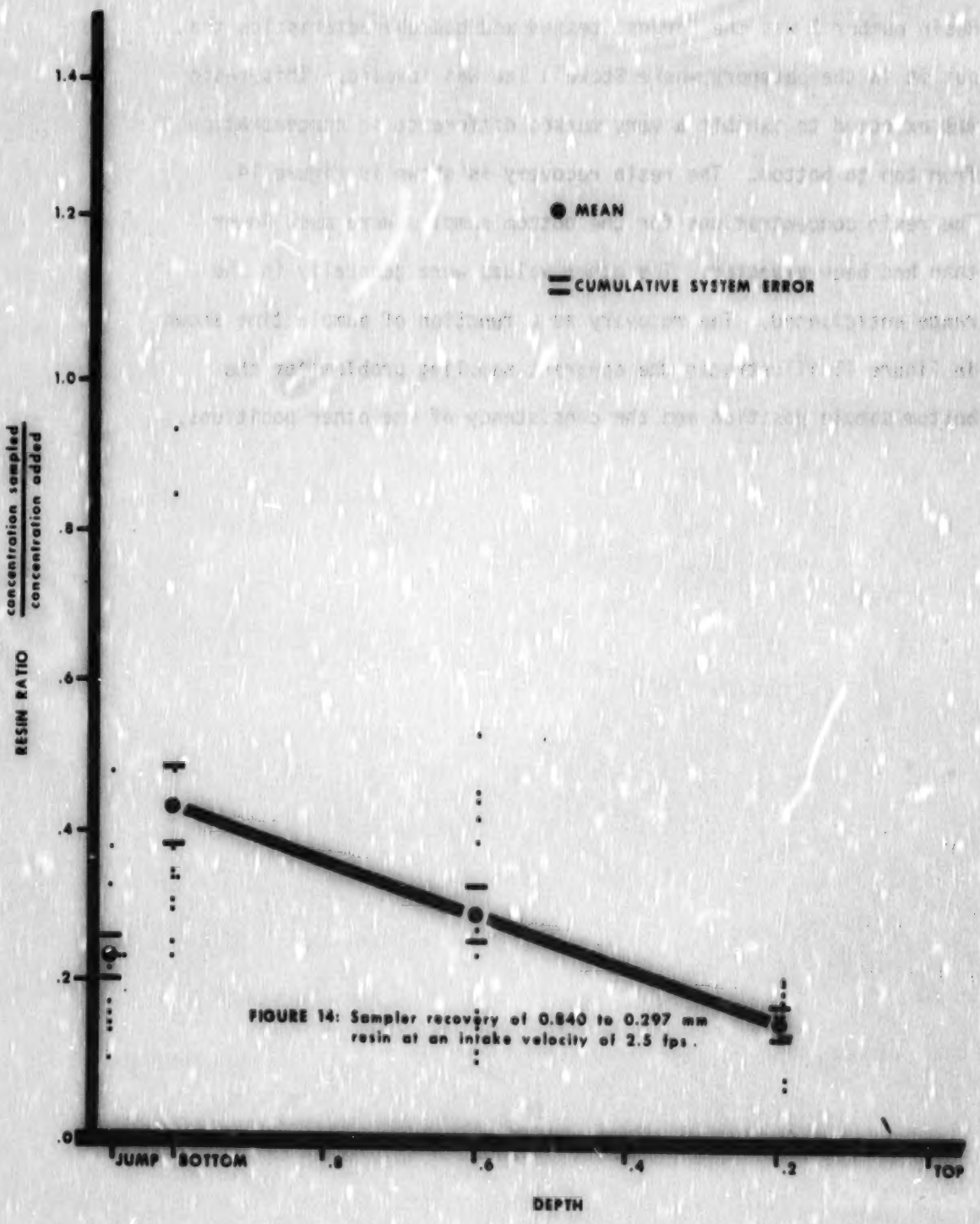

FIGURE 14: Sampler recovery of 0.840 to 0.297 mm resin at an intake velocity of 2.5 fps.

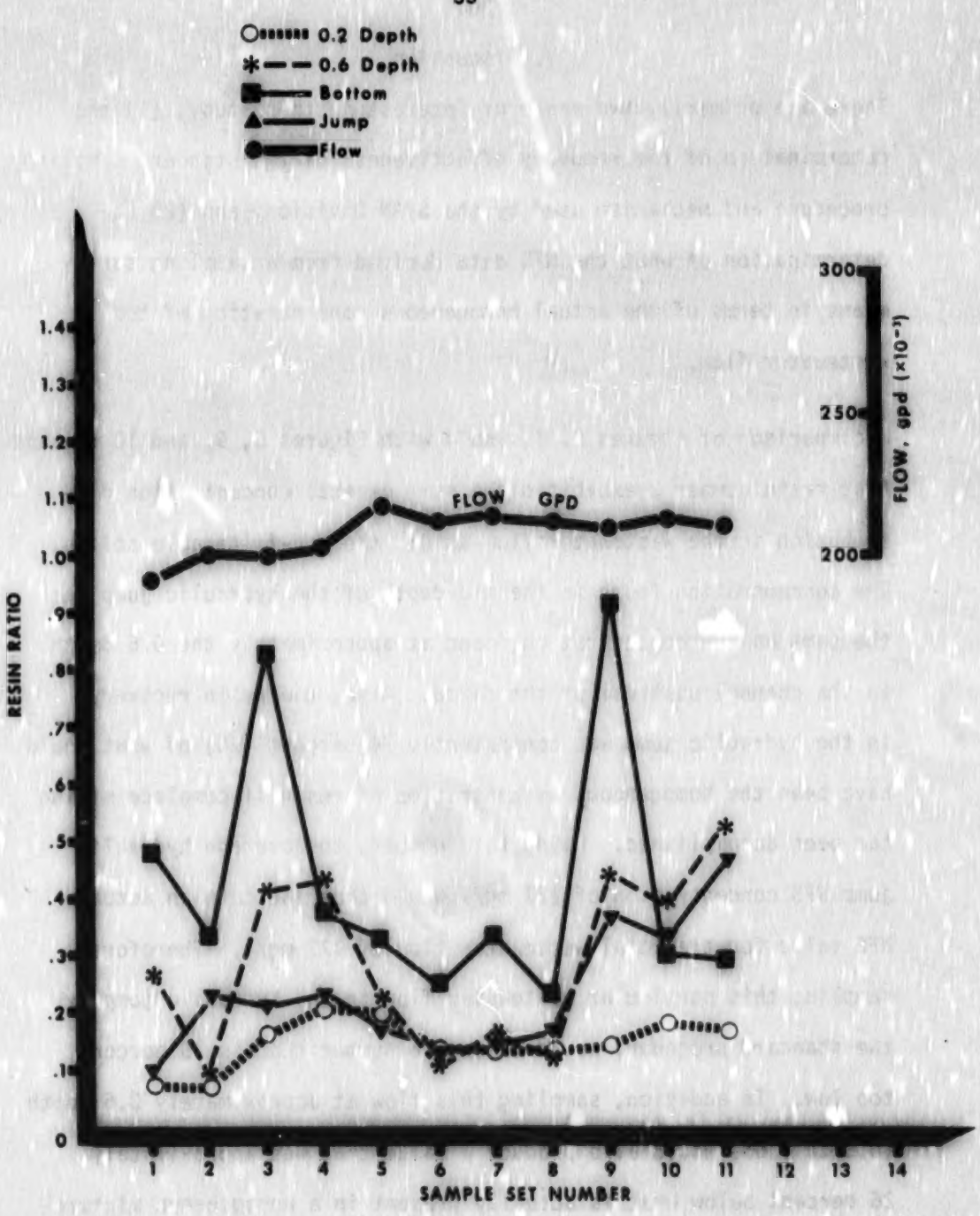

FIGURE 15: Relative recovery of resin #3

V. Discussion

There are primarily two areas of interest in this study, (1) the determination of the recovery effectiveness of the standard sampling procedure and mechanism used by the SVAN Division, and (2) the determination of what the NFS data derived from a sampling survey means in terms of the actual homogeneous concentration of the wastewater flow.

A comparison of Figures 2, 3, and 4 with Figures 8, 9, and 10 reveals that resin number 2 exhibited the same general concentration distribution in the wastewater flow as did the non-filterable solids. The concentration found in the mid-depth of the hydraulic jump was the same as the concentration found at approximately the 0.6 depth in the channel upstream of the flume. Also, the resin recovery in the hydraulic jump was consistently 74 percent (±6) of what would have been the homogeneous concentration of resin if complete mixing had been accomplished. Using this number, the average hydraulic jump NFS concentration of 127 mg/l would then indicate an actual NFS value for the total wastewater flow of 172 mg/l. Therefore, sampling this particular wastewater flow in the hydraulic jump by the standard procedure would produce a number that is 26 percent too low. In addition, sampling this flow at approximately 0.6 depth (0.5 to 0.65) would also produce a value that was approximately 26 percent below what is actually present in a homogeneous mixture of the entire flow. Another way of looking at this sampling infor-

mation would be to state that the sample tube would have to be placed at 0.8 to 0.9 depth in order to recover a concentration that is equivalent to the actual NFS concentration of the wastewater. However, it must be remembered that the change in concentration with depth is very rapid and highly variable at these depths and the positioning of the intake tube would have a very critical effect on the validity of the sample. Another complicating factor is the variation in solids concentration at the lower depths because of inconsistent scouring activity. It would be more reliable to sample at a depth where the change in depth had very little effect on the concentration and then adjust the result to produce the true concentration number. In other words, the wastewater solids distribution would have to be calibrated prior to or during sampling.

Resin number 1, being smaller than resin number 2 and in the region where Stoke's law is valid, should have and did produce a more nearly uniform distribution than resin number 2. Resin number 3, representing the Stoke's law invalid region, was chosen to produce a less uniform distribution than number 2, which it did except for the bottom sample. This may have been caused by deposition of the resin in the sewer pipe, which prevented it from reaching the sample station during the sampling period.

The relationships between the distributions of these three resins can be illustrated by plotting the functional dependence of the

resin recovery on the particle size for each sample position as shown in Figures 16, 17, 18, and 19. The 0.2 and 0.6 depth sample positions, Figures 16 and 17 respectively, produced lower and lower recoveries for larger and larger particle sizes, as would be expected. The apparent misalignment of the data for the largest particle distribution in Figure 16 can be explained by the fact that smallest particles would tend to be the only ones recovered near the surface and consequently, skew the effective size distribution to the left. The bottom samples (Figure 18) did not recover the resin properly. As the particle size increases, the concentration should increase proportionately. The results shown in Figures 16 and 17 indicate a progressive envelope that defines the relationship between recovery at that depth and the particle size. This was not true for resin number 3 at all and the result of resin number 2 may be slightly lower than it actually existed. The envelope described by the first two particle sizes indicated that the largest size distribution should have produced a recovery ratio around 1.5 instead of the 0.45 achieved. The information on Figure 18 supports the conclusion drawn previously that something prevented the proper recovery of the largest resin. There are two possibilities for this discrepency. The sample tube may not have been able to pick large particles up off the bottom of the channel. This possibility does not seem likely since the intake velocity was much higher than the settling velocity of the particles. The other possibility is a leveling

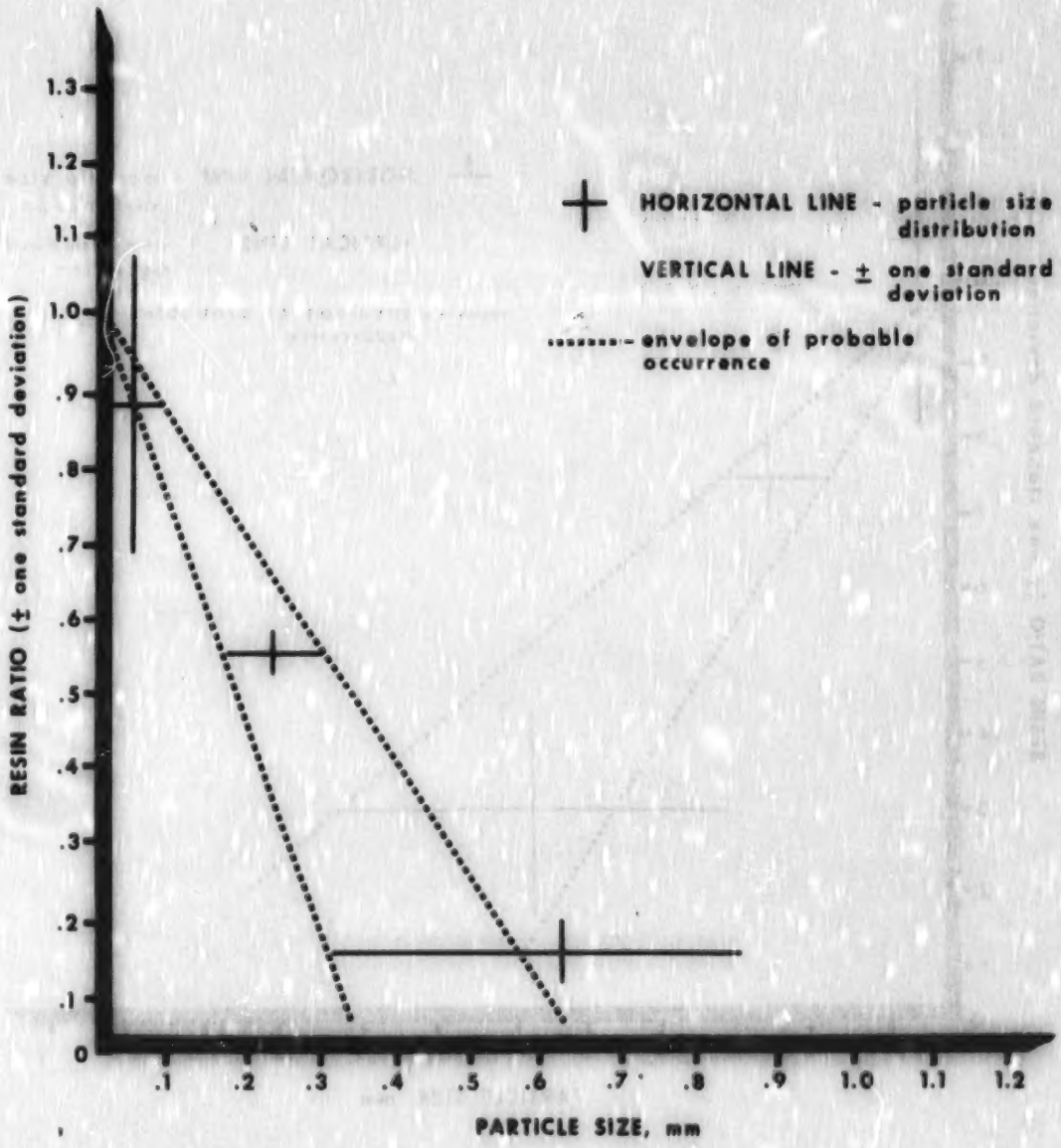

FIGURE 16: Effect of particle size on particle recovery at the 0.2 depth.

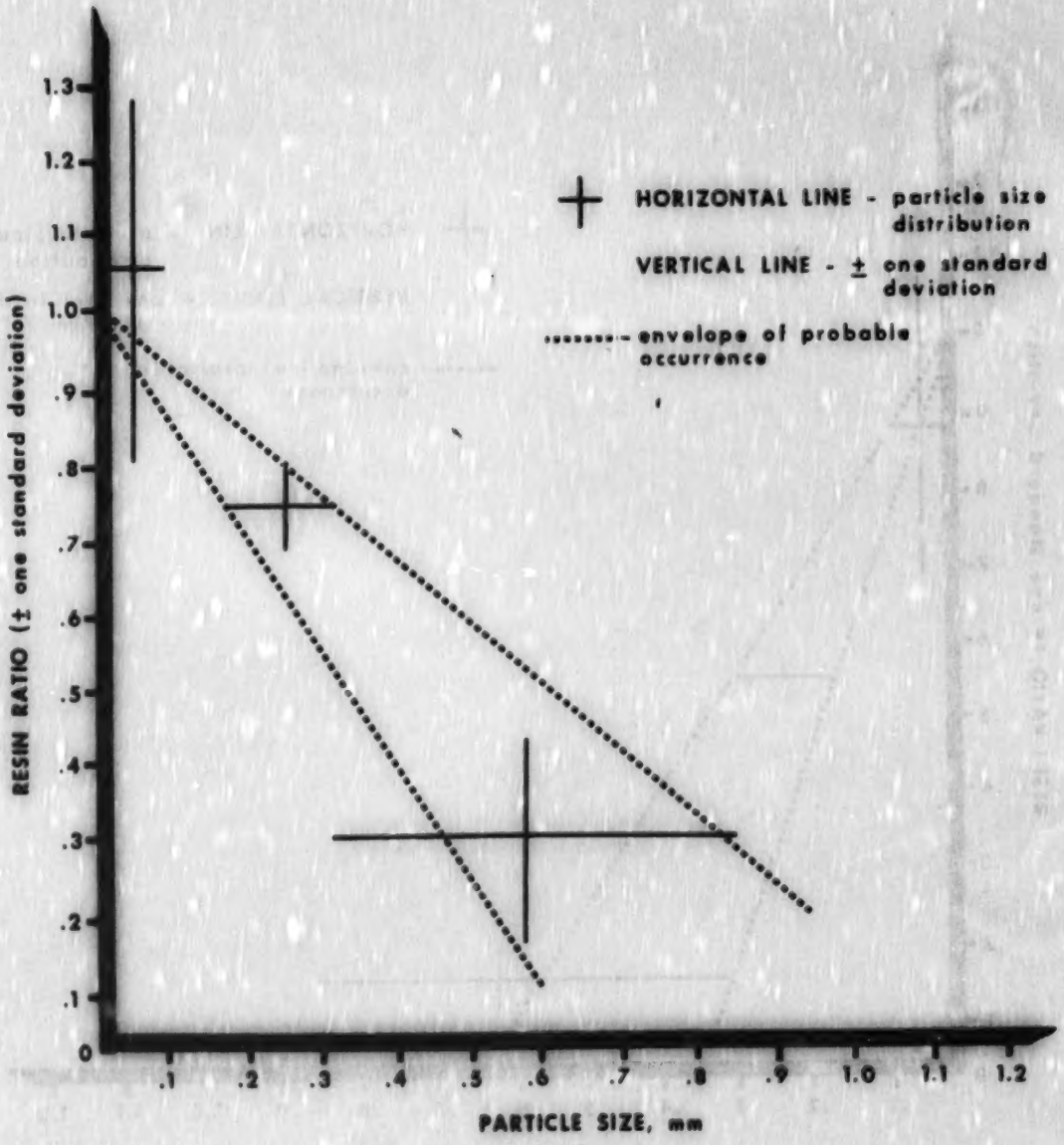

FIGURE 17: Effect of particle size on particle recovery at the 0.6 depth.

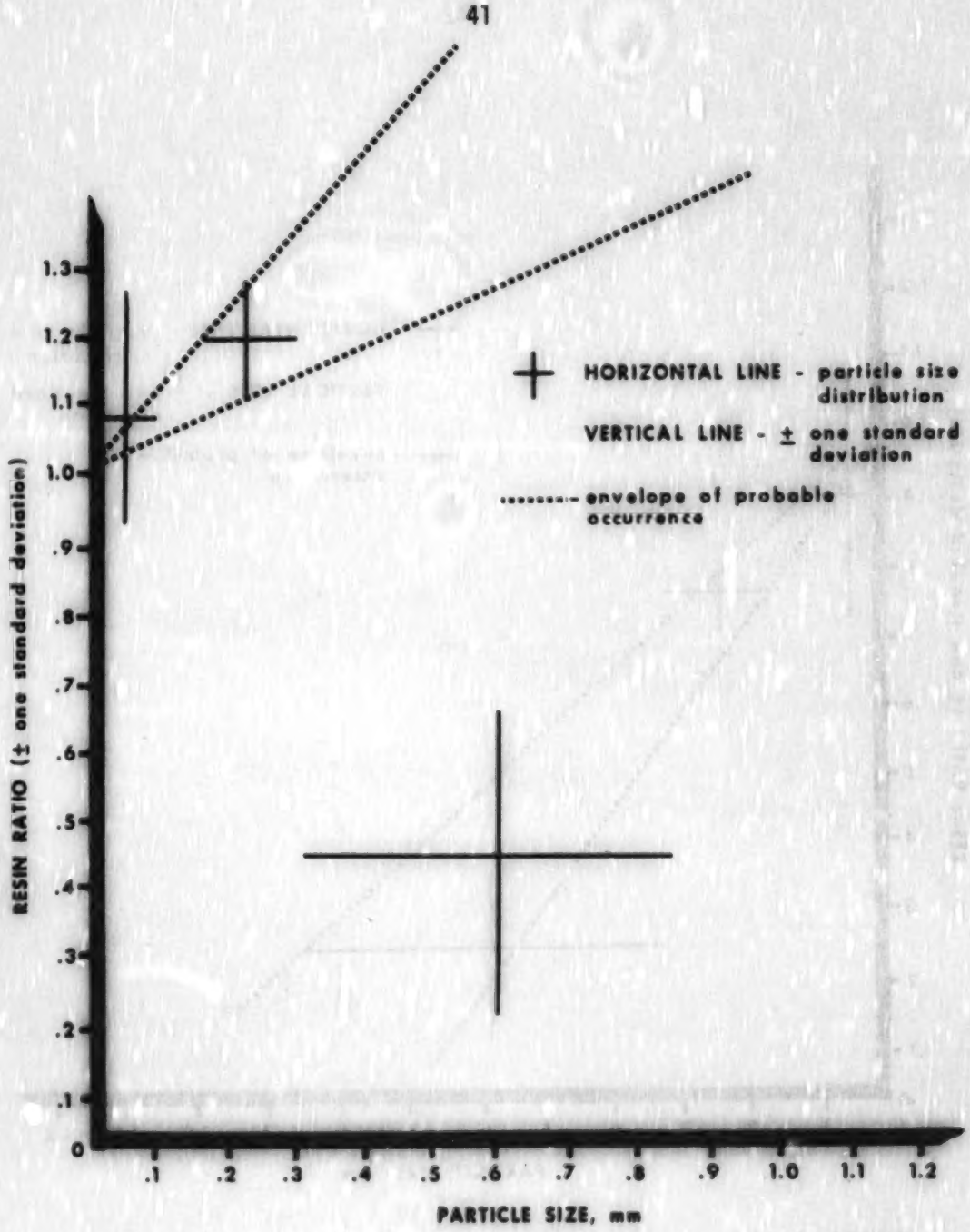

FIGURE 18: Effect of particle size on particle recovery at the bottom of the channel.

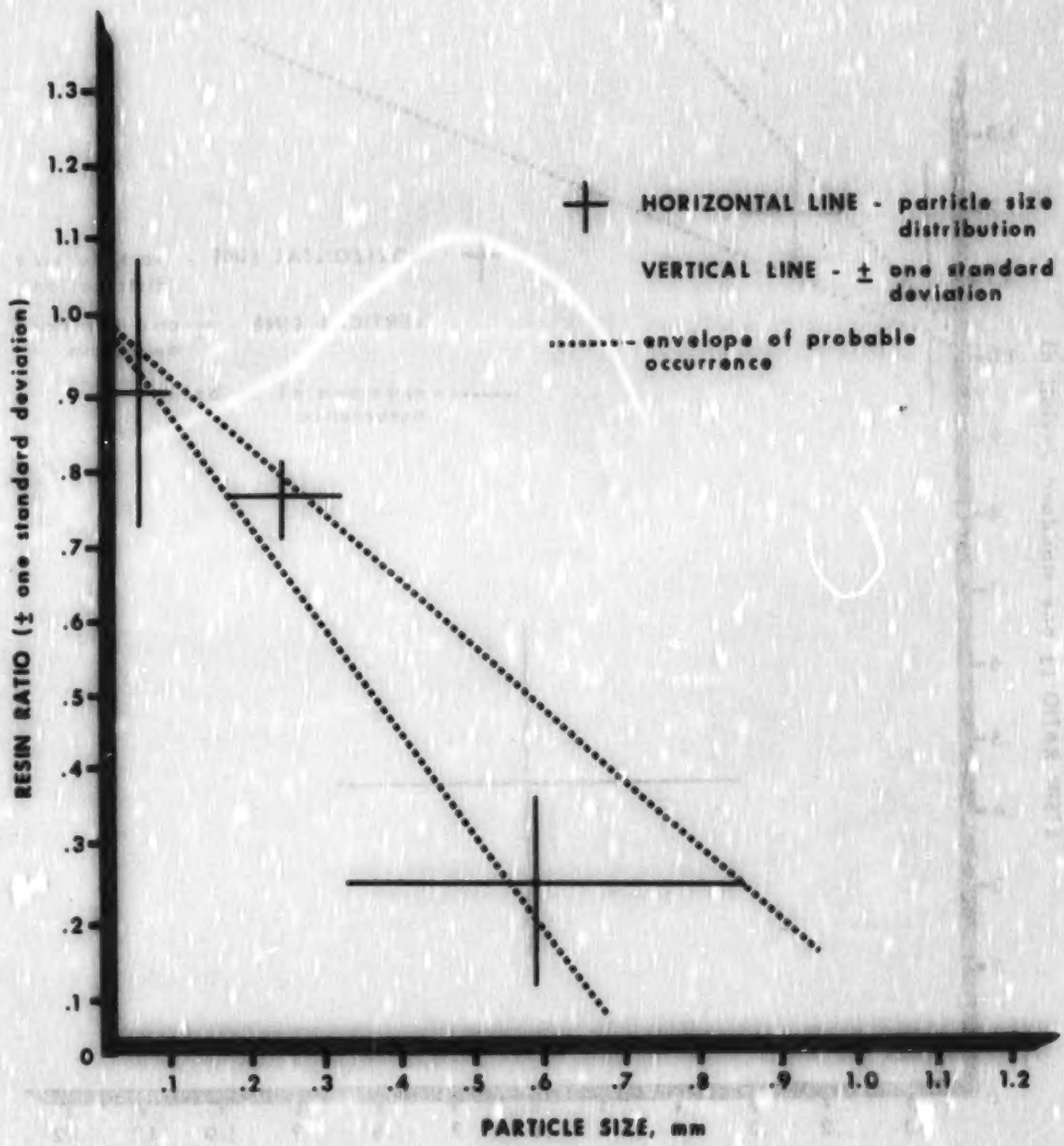

FIGURE 19: Effect of particle size on particle recovery at mid-depth in the hydraulic jump.

of the slope or a "dead" spot in the pipe before it discharged into the entrance structure of the treatment plant. This hydraulic discontinuity would have provided for settling of the resin which may not have had time to work its way down to the sample location during the relatively short sampling period (one-half to three quarters of an hour after the resin feed was started). This condition would also explain why the resin recovery appeared to be directly related to the flow rate. An increase in flow would have tended to flush the system better and decrease in flow would have permitted more settling in the pipe.

The underlying assumption behind all of this data is that the resin actually arrived at the test location. A rough check of the total mass found for resin number 1 and number 2 would indicate that the correct amount of resin did reach the test location. The results for resin number 3 indicate a deficit at the bottom of the channel and possibly a deficit at the 0.6 depth. The possible causes of this deficit have been discussed previously. The resin that appeared at the test section behaved in a predictable manner even if it was sometimes erratic. The same general relationship between the data collected from jump area and the upstream channel held in all cases, however.

The effect of particle size on particle recovery for the sampling station in the hydraulic jump is shown in Figure 19. The data again

defines a progressive envelope to define the functional relationship between size and recovery. A comparison of Figures 17 and 19 reveals that the envelopes of occurrence for the 0.6 depth and the mid-depth in the hydraulic jump were, for all practical purposes, the same. Therefore, either position could be samples and get comparable results. However, it sould be observed that sampling in the hydraulic jump will not necessarily produce a concentration number that is the homogeneous value. The larger, denser particles, occurring predominately on the bottom of the channel, will tend to ride under the turbulence of the jump and not necessarily become remixed into the flow.

An examination of the results of the NFS analyses reaffirms previous statements about its variability with respect to both position and time in a wastewater flow. It is this inherent variability that has produced the questions about the validity of the solids data. This set of conditions must be recognized and lived with. The premise of this study was the need to "calibrate" the wastewater collection characteristics in order to determine the true homogeneous NFS concentration from the samples taken. The results of this study indicate that the NFS distribution conditions can be calibrated by the use of a synthetic wastewater solid that has similar characteristics. The application of this method provides a technique to prove the representativeness of the samples taken from a wastewater stream; which is somethin of concern to surveillance and enforcement personnel.

Even though this study presented additional information about the effectiveness of the standard sampling method and apparatus for monitoring untreated domestic wastewater, it did not provide verification that the same relationships would be true for other equipment or wastewaters. Further study will be required to determine the relative effectiveness between various types of equipment on various types of wastewater.

VI. Conclusions

The information gathered by this study resulted in the following conclusions:

1. A wastewater sampling procedure and mechanism can be "calibrated" for a given wastewater flow by the use of a resin or some similar material.

2. The results for NFS obtained for raw wastewater by the standard sampling procedures used by the EPA Region VII Surveillance and Analysis Division for a wastewater similar to the one used in this study are lower than the actual homogeneous concentrations. In this case, the NFS values obtained at the standard sampling positions were 26 percent lower.

3. Single sampling points should not be located in areas of steep concentrations gradients to minimize the error due to tube location.

4. A method is needed to classify compatible types of sampling equipment and wastewater flows.

VII. Future Work

The need for accurate and reliable non-filterable solids data creates the demand for some method of determining how to sample a given wastewater without expending a lot of time and money. This study has demonstrated the feasibility of using an artificial wastewater solid to determine the accuracy of a sampling procedure. The next step would be to develop a method to quickly and easily match a wastewater to a standard artificial wastewater solid that has been previously "calibrated". This procedure would allow for the determination of the optimum sample collection scheme for the determination of the correction factor to be applied to the data to produce the actual homogeneous NFS concentration value. Additionally, this type of procedure could be used to classify the reliability or accuracy of the different types of automatic samplers when used to sample various types of wastewaters.

The Environmental Protection Agency currently is considering proposals (re. RFP No. CI-76-0260) to include investigations that would provide the answers for the sampler equipment and intake problems along with the preliminary information necessary to begin to determine the feasibiltiy of calibrating a given wastewater to a previously calibrated synthetic wastewater solid, as outlined in the previous paragraph.

The calibration investigation would require the determination of the matching characteristic of the natural and artificial solids. One possibility is that the settling characteristics are sufficient for indexing sampling equipment and methods with wastewater types. Potentially, a settling flux or some similar settling parameter could be used to describe both the natural and synthetic solids to a particular sampling procedure. If this was accomplished, a set of calibrated curves could be developed using the data gathered with synthetic solids relating the flux characteristics of the wastewater solids to the sampling effectiveness in the form of best location of intake, type of equipment, or proper correction factor to be applied to the laboratory data.

A preliminary study to determine whether this type of approach is feasible could be accomplished by a principal investigator, technician, and two lab chemists in a three month period. If the preliminary study proved successful, another three to six months of data collection on various wastewaters could prove its versatility.

VIII. References

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5. Hunter, J.V. and Heukelekian, H., "The Composition of Domestic Sewage Fractions", Journal of the Water Pollution Control Federation, volume 37, August 1965.

6. Eckenfelder, W.W., Industrial Water Pollution Control, McGraw-Hill Book Company, New York, 1966.

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VARIABLE SPEED

WASTEWATER SAMPLER

PURPOSE

This variable speed sampler was developed for use in a study of the pick-up of solids from a wastewater flow. The idea was to have the intake velocity of the sampler as nearly equal to the velocity of the flow as possible. This sampler is also capable of reproducing the intake velocities of many of the commercial wastewater compositors in use.

THEORY OF OPERATION

This sampler was designed around a peristaltic pump driven by a gear-reduced reversible DC motor with a variable speed controller. A Potter & Brumfield KRP 14DG 115VDC relay is used in place of the FORWARD-REVERSE switch on the speed controller. It also switches the motor to full speed when running in the reverse direction (purge cycle). SEE DIAGRAM.

When the manual sample switch is thrown or the switch closes in the HG105A6 timer, power is applied to the motor controller through the CG60A6 timer, the relay through the CG10A6 timer, and the timing device in the CG10A6. This starts the purge cycle which will last for however long the CG10A6 is set for. After that period of time, the switch in the CG10A6 will throw applying power to the timing device in the CG60A6 and allowing the relay to return to the sample cycly position. A sample will be drawn at the speed set on the speed

controller for the length of time set on the CG60A6. The switch in the CG60A6 will then throw and disconnect the power from the motor controller.

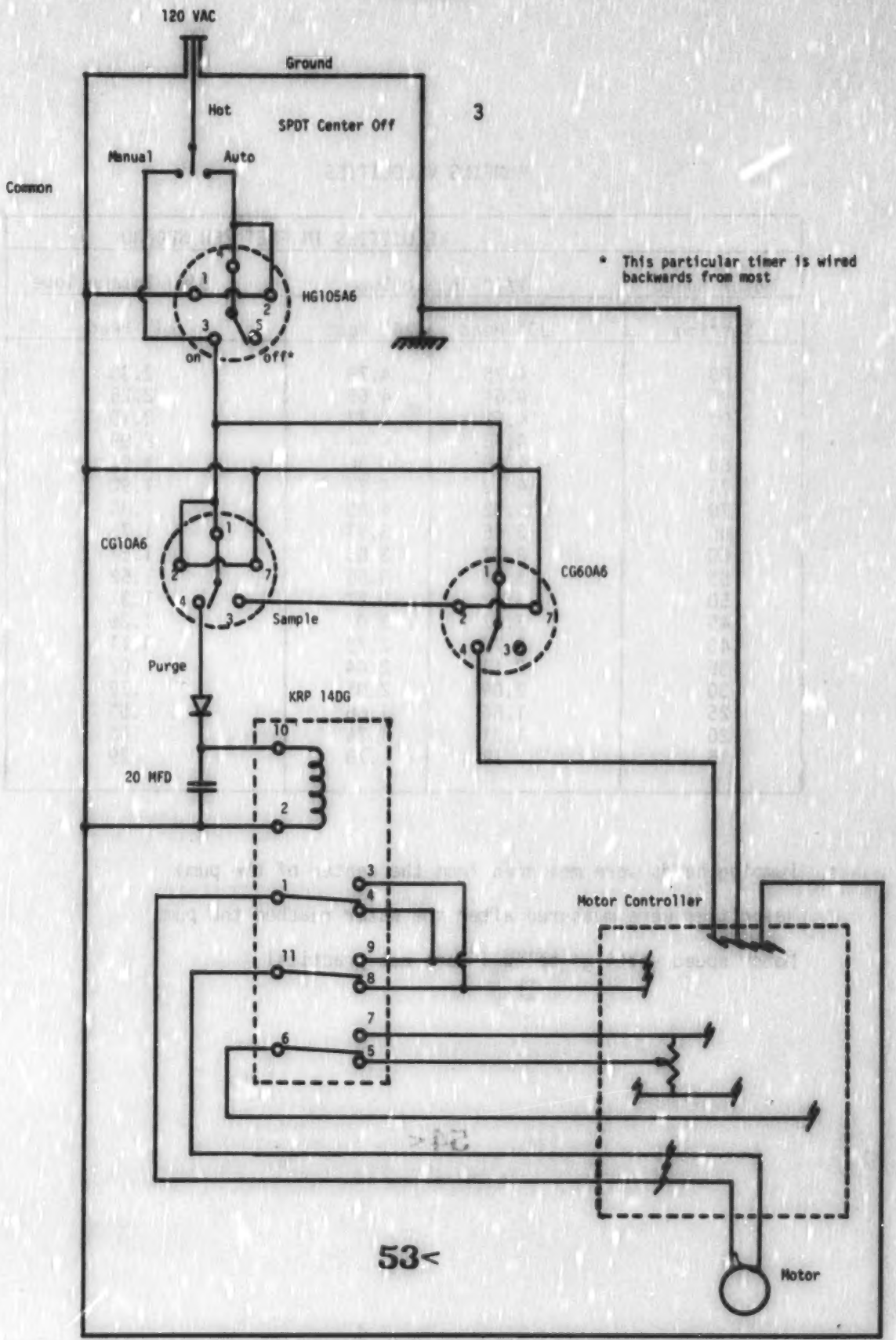
The CG10A6 and CG60A6 timers will reset themselves when power is removed by either moving the manual switch to "off" or the switch in the HG105A6 timer returns to "off."

FUTURE ADDITION OF POST-PURGE

A post-purge cycle may be added, if desired, by simply connecting Pin #3 of the CG60A6 to Pin #4 of the CG10A6. After the sample is drawn, it will purge until the manual switch is thrown off or the switch in the HG105A6 returns to "off."

A timed post-purge may be added with the use of another CG10A6. Pin #3 of the CG60A6 should be connected to Pins #1 and #2 of the new CG10A6. Pin #7 of the new CG10A6 should go to common (Pin #7 of the CG60A6, etc.) and Pin #4 of the new CG10A6 should go to Pin #4 of the first CG10A6. It will then post-purge for however long the new CG10A6 is set for.

WIRING DIAGRAM



PUMPING VELOCITIES

	VELOCITIES IN FEET PER SECOND		
Motor Speed	1/4" Intake Tube		3/8" Intake Tube
Setting	30" Head	24" Head	24" Head
100	4.75	4.79	2.30
95	4.64	4.66	2.26
90	4.62	4.47	2.19
85	4.46	4.41	2.09
80	4.40	4.30	1.96
75	4.13	4.21	1.90
70	4.02	4.00	1.80
65	3.96	3.97	1.73
60	3.77	3.85	1.61
55	3.54	3.56	1.52
50	3.33	3.27	1.37
45	3.07	3.07	1.26
40	2.76	2.73	1.11
35	2.44	2.44	.97
30	2.09	2.05	.79
25	1.66	1.66	.63
20	1.21	1.24	.48
15	.72	.78	.29

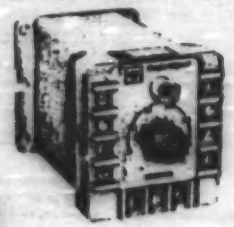
Pumping heads were measured from the center of the pump

Velocities were measured after the water reached the pump

Motor speed settings below 15 are not practical

BULLETIN 158
TIME DELAY RELAY
CG/CG000 SERIES — ON DELAY

CG000A . . . Time Delay Relay Plug-In Octal Base



CG000AS . . . Time Delay Relay Surface Mounting

CG000 Series . . . Panel Mounting

55A

Versatile . . . Compatible . . . Solid State

The "CG" series time delay relay, available in either the octal base plug-in case or the surface mounting case is a versatile, highly compatible time delay relay.

Octal Base Plug-In Case

- Available with 8 pin or 11 pin plug.
- Plugs into standard 8 or 11 pin socket.
- Case of high impact resistant dyestuff.
- Models available for remote operation.
- Models available with fixed timing period.

Surface Mounting Relay Case

- Case of flame proof, high impact resistant Meryl.
- Case material recognized by UL as safe support device for current carrying components.
- Pilot light standard.
- Models available for remote operation.
- Models available with fixed timing period.

SPECIFICATIONS

BULLETIN 158

Selection Chart

STOCK NUMBERS		DIAL SPECIFICATIONS		
Plug-In	Surface Mtg. Case	Dial Range	Minimum Timing	Dial Divisions
CG0A4	CG000A4	2 Sec.	.020 Sec.	.2 Sec.
CG10A4	CG010A4	10 Sec.	.060 Sec.	1 Sec.
CG30A4	CG030A4	30 Sec.	.150 Sec.	3 Sec.
CG60A4	CG060A4	60 Sec.	.300 Sec.	5 Sec.

Electrical Ratings

Coil 120 volts 50/60 cycle 2.5 watts.
Also available for 240V. 50/60 cycle; 12, 24, 110 volts D.C. on special orders.

Contact Rating

10 Amps. 120 V.A.C.
CG-DPDT
CG000-SPDT

Reset Time

50 milliseconds minimum off time is required to reset the timer.

Dial Setability

Dial Reads directly in seconds.
Time Delay will be within 10% of full scale.

Repeat Accuracy

± 2% at 102 to 132 voltage variation.
+ 10% at temperature increase to 140°F.

Mounting

See page 2.

Mechanical Life Expectancy

24 million operations.
1 million operations @ 10 amp.
120 VAC resistive

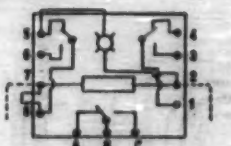
BULLETIN 158
TIME DELAY RELAY
CG SERIES

WIRING DIAGRAMS

Standard On Delay Operation

CG

Apply power to pins 2 and 7 to start timing. After delay contacts 1-4 and 8-5 open, 1-3 and 8-6 close. Removing power resets contacts to original position shown.



CG000

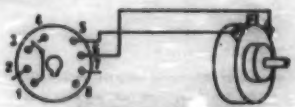
Apply power to pins 2 and 7 to start timing. After delay contacts 1-4, 8-5, and A-8 open, 1-3, 8-6, and B-C close. Removing power resets contacts to original position shown.

TIME ADJUSTMENTS

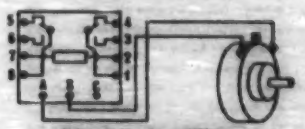
The standard "CG" timer is furnished with a knob mounted on top which is used to adjust the time delay. By ordering this unit with the suffix "-02" or "-04" (see chart) it is furnished without the knob and wired as shown so that an external potentiometer can be used. The potentiometer should be connected with either a shielded lead or twisted pair of wires. Eagle Signal has available a "remote pot kit" which includes the knob, dial, and 2 watt potentiometer to be used when remote setting is desired.

TYPE			Potentiometer Resistance	Remote Pot Number
Octal Plug-In	Surface Mtg. Case	Dial Range		
CG0A4	CG000A4	2 Sec.	1 Meg. Ohm.	CG10-70
CG10A4*	CG010A4	10 Sec.	1 Meg. Ohm.	CG10-71
CG30A4*	CG030A4	30 Sec.	750,000 Ohm.	CG10-72
CG60A4*	CG060A4	60 Sec.	750,000 Ohm.	CG10-73

*"-02" feature applies to the CG relay and is an 8 pin plug-in relay with 5000 resistor "04" feature applies to either CG or CG000 relays and is either an 11 pin plug-in relay (CG) or 11 terminal modular rail relay case (CG000) with 5000 rotary.



CG with "02" Remote 5000 Output.



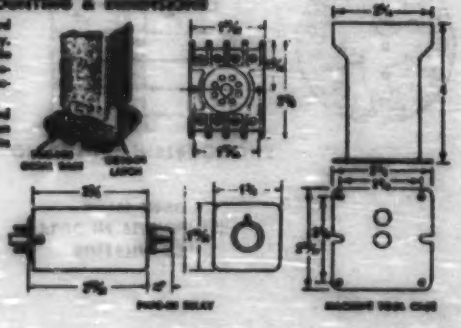
CG000 with "04" Remote 5000 Output.

IMPORTANT: Leads to Remote Potentiometer are susceptible to transient voltages which could cause the timer to malfunction. In general the effects of transients is to accelerate the timer. It is recommended that the leads to the Potentiometer be either shielded or shielded. The shield should be connected to the neutral conductor.

MOUNTING & DIMENSIONS

The "CG" timer will plug into any standard octal base, even one wired for a relay, where a time delay is required. The Eagle PDC-198 base is recommended as it provides screw terminals for making connections.

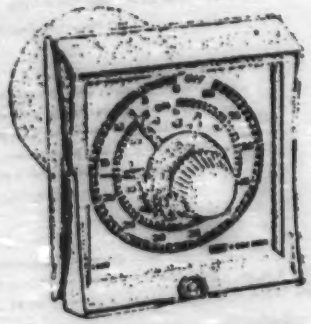
Where the timer is mounted horizontally and vibration is present, the CG10-04 knob can be used to positively lock the relay in its socket.



PLUG-IN RELAY

MOUNTING HOLE CUT

BULLETIN 321
PLUG-IN FLEXOPULSE
(HG100 SERIES)



. . . Closes and opens contacts repeatedly as long as the timer is energized.

FEATURES

- Two 10 Amp. single pole double throw switches.
- Timer can be adjusted anytime during time cycle and will immediately pick up new setting.
- Time range of unit controlled by synchronous motor thus eliminating complicated gear changing.
- Stainless steel directional control mechanism gives test proven life of over 10 million operations.
- Color keyed knobs and dial for easy, accurate reading and setting.
- Cycle Progress Pointer allows for checks on progress at anytime.
- HG100 offers a wide selection of cycle ranges.
- Plug-in feature provides instant interchangeability.

Figure 1

OPERATION

The HG Series Flexopulse has 2 time scales on the dial. A black outer scale for the "OFF" time and a blue inner scale for the "ON" time. Each time scale has a color keyed dial pointer and knob for setting the exact "on" and "off" time desired. An indicator pointer continuously oscillates between the settings of the two pointers. Switches are transferred each time the indicator pointer passes "0."

A synchronous uni-directional motor drives the unit through precision gearing. Instant reversing of the unit is obtained by positive mechanical action. The plug-in Cyd-Flex case provides flexibility and neat appearance.

SPECIFICATIONS

Standard Time Ranges

Catalog Number	Dial Range	Minimum Setting	Repeat Accuracy	Max Time Setting (Approx.)
HG100A00	30 Sec.	.5 Sec.	±.15 Sec.	.5 Sec.
HG101A6	60 Sec.	1 Sec.	± .3 Sec.	1 Sec.
HG102A6	120 Sec.	2 Sec.	±.75 Sec.	2 Sec.
HG103A6	5 Min.	5 Sec.	±1.5 Sec.	5 Sec.
HG104A6	15 Min.	10 Sec.	± 3 Sec.	10 Sec.
HG105A6	30 Min.	20 Sec.	± 9 Sec.	30 Sec.
HG106A6	60 Min.	1 Min.	± 15 Sec.	1 Min.
HG107A6	120 Min.	2 Min.	± 45 Sec.	2 Min.
HG108A6	5 Hr.	5 Min.	±1.5 Min.	5 Min.
HG109A6	10 Hr.	10 Min.	± 3 Min.	10 Min.
HG110A6	30 Hr.	30 Min.	± 9 Min.	30 Min.
HG111A6	60 Hr.	60 Min.	± 15 Min.	60 Min.

Accuracy

½ of 1% of Dial.

Electrical Rating

120 Volt, 50 Cycle — 120 Volt, 60 Cycle
240 Volt, 50 Cycle — 240 Volt, 60 Cycle

Contact Ratings

10 Amp, 120 volts AC and 5 Amp, 240 volts AC resistive load.

Mechanical life 10,500,000 operations.

Switch life 250,000 under 10 Amp, 120 VAC resistive load 1,000,000 under 5 Amp. 120 VAC resistive load.

Temperature Range

–20° to + 140°F.

Enclosures and Accessories

Refer to Cyd-Flex section of Bulletin 2500.

Dimensions

Refer to page 2.

OPERATING INSTRUCTIONS

Figure 2

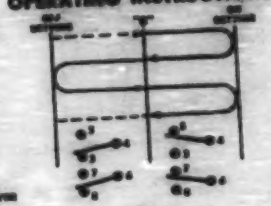


Figure 3

Figure 4

To set: Move the black pointer to the desired "OFF" setting and the blue pointer to the desired "ON" setting. The sum of these "ON" and "OFF" intervals cannot exceed the total time of one scale. Switch contacts are tripped open or closed each time the indicator pointer passes "0." When the indicator pointer is in the "OFF" scale to the left of "0" contacts 4-5 and contacts 6-8 are closed and 4-6 and 6-7 are open. When the indicator pointer is in the "ON" scale to the right side of "0" contacts 4-5 and 6-7 are closed and 4-6 and 6-8 are open. The indicator pointer must travel to the point it left and back to "0" to complete the total "ON" or "OFF" interval. The two switches can operate together or be set to provide a dwell interval or overlap between "ON-OFF" switching. Refer to the standard time range chart under specifications for the maximum dwell interval for each time range. Figure 3 illustrates the path of the indicator pointer and the switch action each time the zero point is passed. Figure 4 illustrates the terminal location on the rear of the unit case.

MOUNTING DIMENSIONS

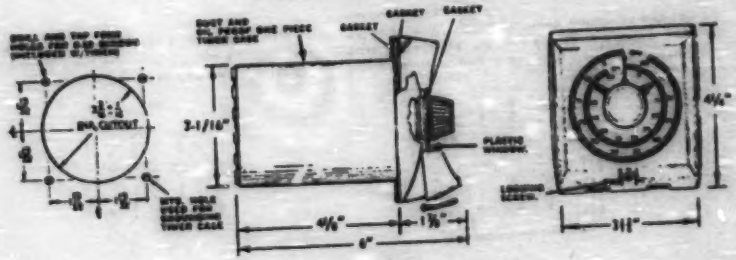


Figure 5

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